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NOTES ON THE WINDOW GNATS, GENUS SYLVICOLA (DIPTERA; ANISOPODIDAE), IN SCOTLAND

By E.G. HANCOCK
Department of Natural History, Glasgow Museum and Art Gallery

Introduction

All four known British species in the fly genus *Sylvicola* Harris, 1780 have been found in Scotland, although their distribution is not comprehensively understood. The readily available literature (Edwards, 1928; Freeman, 1950) does not include reliable characters for separating the females of three of the species. To provide such a key should therefore be useful in itself, since unassociated females are often present in a sample from a site. It has also been the case that earlier records involving males are suspect because of reliance on colour characters only. Keys are given below to both sexes of all the species, together with brief notes on their biology, and it is hoped these will encourage the recording of this small but distinctive and interesting group of widespread insects.

In general, the adults of *Sylvicola* can be found in some numbers when at rest on walls or tree trunks and during swarming. The common name 'Window' Gnat is probably derived from the tendency to congregate on windows in houses, the insects having been attracted indoors and then trying to get out again. Rotting or fermenting vegetable matter is the principal food of the younger stages. In less hygienic times these flies survived and bred inside dwelling places, which might further explain the acquisition of such a vernacular name. They are a common component of light traps and other catches such as those from Malaise traps. Their abundance is further reflected by constant presence in sweep-net samples. It is probable that the various species play an important role in the breakdown of organic matter, although apart from some work with rotting fruit in Australia (Atkinson, 1985) this does not seem to have been quantified.

Sylvicola punctatus (Fabricius, 1787)

This species is abundant and widespread, particularly in association with pasture since the larvae are usually found feeding in the dung of domesticated herbivorous mammals. It is easily distinguished from the other British species in the genus by having a clear tip to the wing, thus making it

unnecessary to resort to genitalic structure for identification. Recently *S. punctatus*, and other similar species not found in this country, have been placed in a separate subgenus, *Anisopus* Meigen, 1803 (Pratt and Pratt, 1980). On a worldwide basis this makes a useful contribution to handling over one hundred species currently known.

Sylvicola cinctus (Fabricius, 1787)

In morphological terms *S. cinctus* is typical of the remaining three species, but there is considerable variation in colouration, which can make the use of earlier keys subject to ambiguity. To distinguish the following species the genitalia are used at some point in the keys. In the males it is not normally necessary to resort to dissection, and in the females, although the key character does lie in an anatomical structure, it is normally discernible with low power magnification (x 20). This structure is the vaginal apodeme, a sclerotised plate which supports the genital chamber. Useful features are embodied in its distal parts, as indicated in the accompanying diagrams. These features are visible in fresh specimens or those preserved in fluid, with a small amount of manipulation. In dried material, softening is required, using a technique such as that described by Speight (1982) or clearing with caustic potash in standard entomological practice. The apodeme has been used to distinguish between females of *cinctus* and *fenestralis* (Pederson, 1968) but *zetterstedti* has not previously been figured.

S. cinctus in the larval form is found in a variety of rotting vegetable matter and is easily bred in captivity on rotten apples. It occurs also at the bases and in the roots of umbelliferous plants, a habitat it shares with *zetterstedti*. As with the latter species, if these plants are brought indoors the adult insects emerge early in the year, usually in February. I have recently reared *cinctus* from Giant Hogweed *Heracleum montegazzianum*, a previously unrecorded food-plant, growing on the banks of the River Clyde at Carmyle, Glasgow. Unlike *zetterstedti*, *cinctus* can be found in every month of the year. Whenever the temperature rises above about 8°C *cinctus* can be found in traps, and the indication is that in some situations the adults are capable of hibernating.

There are several examples of confusion between *cinctus* and the following species in the literature; e.g. Abul-Nasr (1950) published an extremely detailed account of this species but referred to it throughout as *fenestralis*. It seems likely that *cinctus* is the most common species in the British Isles.

Sylvicola fenestralis (Scopoli, 1763)

S. fenestralis has been recorded from a variety of situations, which indicate it has a tendency to utilise animal protein as well as vegetable matter. If it has been correctly identified on each occasion, this species forms one of the elements of the insect fauna of sewage farms (e.g. Tomlinson, 1946). Edwards (1928) recorded *fenestralis* larvae in a piece of mouldy liver which had previously been immersed in a solution of formaldehyde for several years. Several reports exist of *fenestralis* larvae as facultative parasites in humans (Smith and Taylor, 1966). Apart from these examples, it shares the family liking for rotting vegetation and has been identified as a spoiling agent in cider and wine processing. These various occurrences make the family of direct economic and medical importance.

This species is rarely recorded in Scotland. Specimens supporting earlier records which I have been able to examine in the Royal Museum of Scotland have proved to be *cinctus*, and a more extensive examination of preserved material corollated with published references is required. *S. fenestralis* is definitely uncommon in Scotland and old records unsupported by voucher specimens would be unacceptable. I personally have taken *fenestralis* three times in Lanarkshire (1984-87) and once in Nairn (1983).

Sylvicola zetterstedti (Edwards, 1923)

There appear to be only two Scottish localities for this species as quoted by Young (1976). The record given therein as Banffshire should read Nairn, from where it was collected by Colonel J.W. Yerbury on 31st May 1908. Following Young's record at Castle Corner, Caerlaverock, Dumfriesshire, I have collected eggs and larvae from this area and reared this species from both Common Hogweed *Heracleum sphondylium* and Angelica *Angelica sylvestris*, which are the only two known food-plants.

Most records of the adults of *zetterstedti* are from April and May, but it is not restricted to the spring and there are probably two generations per year. As with *cinctus*, the flies emerge earlier if kept indoors. In one case I have reared both species from the same roots and *cinctus* emerged before *zetterstedti*.

Males of *zetterstedti* can easily be distinguished from other species within the British fauna because the eyes are very close together. In the female the abdomen has a tendency to be distinctly reddish, especially when alive, and the wing

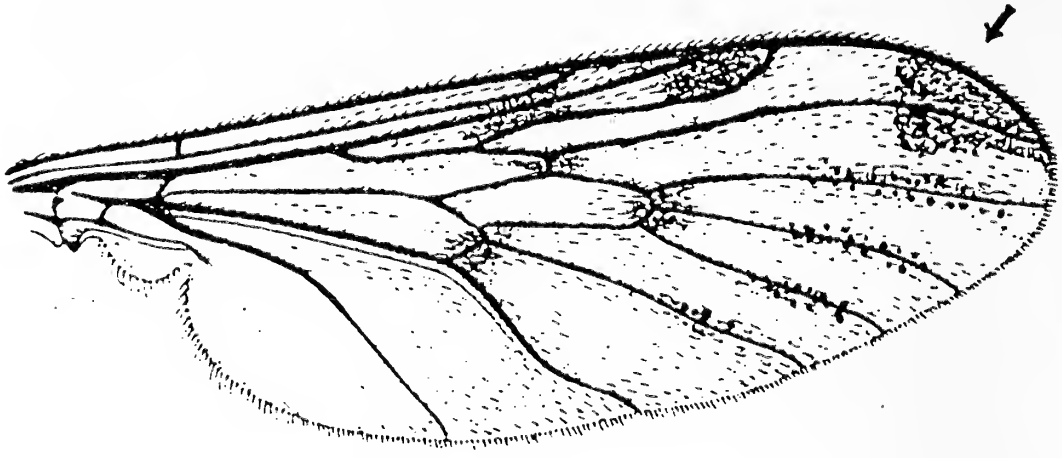

Figure 1

Wing of *Sylvicola zetterstedti*

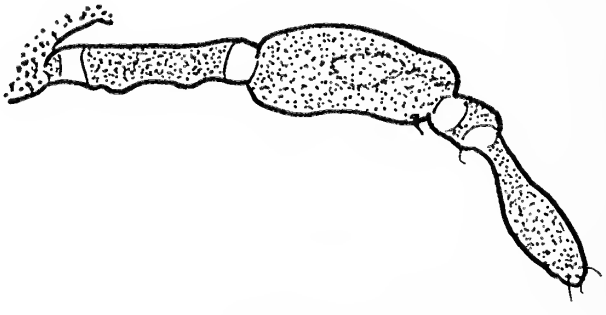

Figure 2

Palp of female *Sylvicola cinctus*

markings are strongly pronounced (Figure 1), but as with other colour features these are subject to variation and unsuitable as primary key characters.

It remains to be seen if *zetterstedti* is actually more common than the current sparse scattering of records throughout Europe indicates. I have reared *zetterstedti* from Angelica growing near Howbeg, South Uist. Egg masses and larvae were common in the basal leaves of the growing plant in early July 1988, and adults emerged throughout September and October. This demonstrates both that the living host plant is invaded and also that two generations can certainly occur in one year.

Sexual Characters

To distinguish males from females in the genus is relatively simple. The genitalia of the male are externally visible, and torsion of the abdomen means that the extremity of the abdomen is held at an angle of between 45°-90° to the horizontal plane of the body. The abdomen is thinner than that of the female and is usually darker towards the tip. The eyes of the males are close together, and in the case of *zetterstedti* particularly are separated by a very narrow gap.

The maxillary palps also differ. The females have a swollen antepenultimate segment, being more than twice the diameter of the other segments (Figure 2). The equivalent in the male is only slightly larger than the others and in both sexes this segment carries sensory organs. There are similar organs in the basal flagellar segments of the antenna of males of *S. punctatus*. These are absent in the other British species, and may be of diagnostic value at a higher level of classification.

The features of the structure of the apodeme can be seen in fresh specimens by gently squeezing the abdomen. The tips of the sclerotised rods and their disposition, if present, can then be detected.

Keys

As a general introduction to the study of flies, and to assist in placing them in the right families, the works of Colyer and Hammond (1968), Stubbs and Chandler (1978) and the AIDGAP key (Unwin, 1981) are invaluable.

It is hoped that the accompanying keys will assist with the identification of the four species. In earlier keys (Edwards, 1928; Freeman, 1950), a melanic form of *cinctus* (var. *withycombei* Edwards, 1926) was mentioned but is not included here.

Key

Males

1. Wing tip clear ---------- *punctatus*

   Wing tip clouded (Figure 1) ---------- 2

2. Eyes nearly touching, only the width of one eye facet separating them below the antenna (genitalia Figure 5) ---------- *zetterstedti*

   Eyes separated by more than the width of an eye facet ---------- 3

3. Genitalia with median part of ninth sternite broad; claspers with basal tooth; parameres blunt-tipped (Figure 3) ---------- *fenestralis*

   Genitalia with median part of ninth sternite narrow at tip and with lateral teeth; claspers without basal tooth; parameres distinctly scimitar shaped at tip (Figure 4) ---------- *cinctus*

Figures 3-5

3. Genitalia of male *Sylvicola fenestralis*

4. Genitalia of male *Sylvicola cinctus*

5. Genitalia of male *Sylvicola zetterstedti*

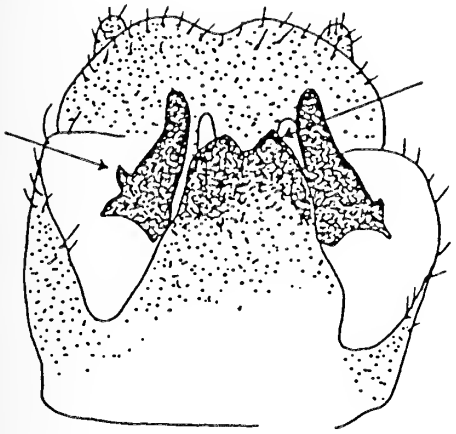

Figure 3

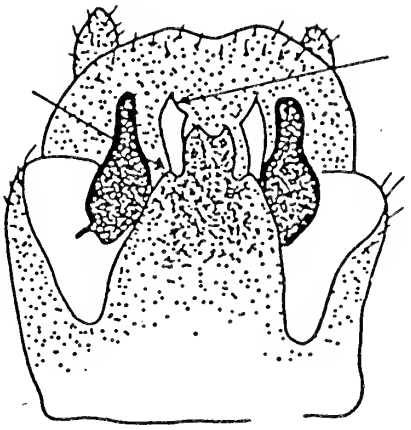

Figure 4

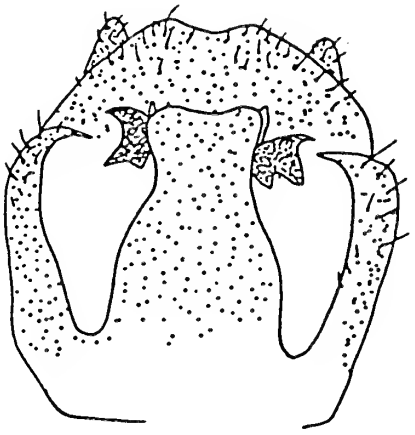

Figure 5

Key

Females

1. Wing tip clear ---------- *punctatus*

   Wing tip clouded apically (Figure 1) ---------- 2

2. Apodeme with lateral leaf-shaped extensions and no heavily sclerotised rods (Figure 6) ---------- *fenestralis*

   Apodeme with sclerotised rods centrally (Figures 7 and 8) ---------- 3

3. Rods more pronounced and nearly parallel (Figure 7) ---------- *cinctus*

   Rods diverging at nearly a right-angle (Figure 8) ---------- *zetterstedti*

Figures 6-8

6. Apodeme of female *Sylvicola fenestralis*

7. Apodeme of female *Sylvicola cinctus*

8. Apodeme of female *Sylvicola zetterstedti*

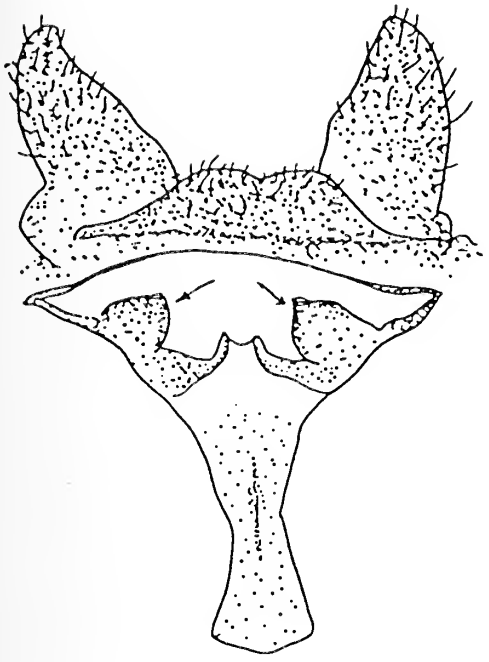

Figure 6

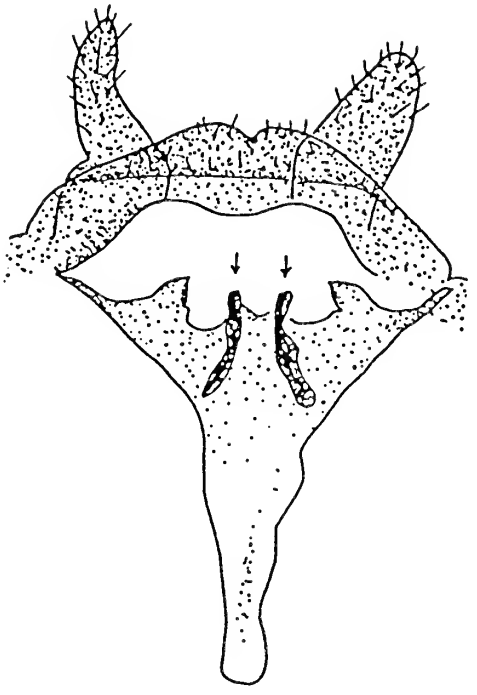

Figure 7

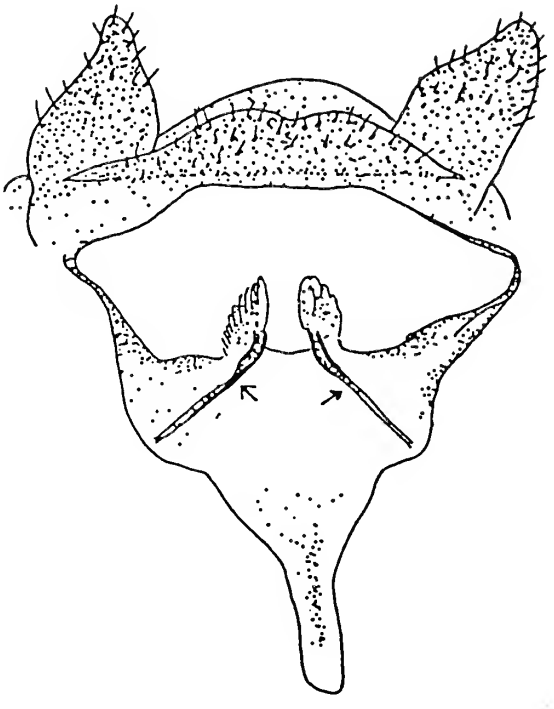

Figure 8

Summary

It is hoped that both the general information and some of the problem areas indicated above will stimulate interest in these common flies. Although one of the smallest families in terms of species, the number of fundamental questions still to be addressed and resolved is large. Their distribution in Scotland has not yet been analysed in any detail and there is scope for much basic natural history investigation.

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Mr. E.G. Hancock, Department of Natural History, Glasgow Museum and Art Gallery, Kelvingrove, GLASGOW G3 8AG.

THE 1987 CENSUS OF GANNETS ON AILSA CRAIG

By J.A. GIBSON
Clyde Area Branch,
Scottish Wildlife Trust

The 1987 census of the Ailsa Craig colony of Gannets *Sula bassana* again took the form of a one-day census made from the sea in early May, with the usual check counts of selected control areas later in the year.

Present Population

The detailed counts for 1987 are given in Table 1, along with the usual comparative counts for the previous three years. As before, all are direct counts through binoculars of occupied nests, and all figures comprise the mean of several counts of each cliff-section, made at different times throughout the same day from the same counting-stations. Only occupied nests are counted; all Gannets not occupying nests are ignored. Control counts made later in the year (all of which again confirmed the figures of the one-day census in early May) are used only as checks, and are not included in the official census.

No further population 'crashes' have taken place since 1975, and the colony has continued to increase steadily each year. In some previous years this increase was at the rate of nearly 1,000 nests a year, but there is now a real indication of a reduction in this rate of increase. The increase reported for 1985 was 814 nests, for 1986 was only 231 nests, and this year (1987) is 569 nests. Neverless, the 1987 count of 23,611 occupied nests is again the highest population of Gannets ever to have been recorded for Ailsa.

Index of Room

There is now very little point in producing the annual 'index of room' available for Gannets on Ailsa Craig. As previously reported, the extension and merging of the traditional areas of the Ailsa cliffs occupied by breeding Gannets has made the previous index of the amount of 'room' available for Gannets on Ailsa largely irrelevant. Moreover, Gannets continue to utilise the sloping ground at the tops of the cliffs, where they are steadily extending their nesting areas, so, if this continues, clearly there is almost no limit to the size of the breeding population which Ailsa can hold. With the steadily increasing size of the breeding colony, the

Table 1

Counts of Gannet Nests on Ailsa Craig
1984 - 1987

Total for each cliff section represents the mean of several separate counts

Colony	1984	1985	1986	1987
Sliddery	348	371	390	399
Sliddery, Top Ridge	506	548	538	562
North of the Slunk	501	536	549	553
Foot of the Slunk	597	629	638	650
Above Ashydoo	287	299	307	343
Balvaar	1037	1083	1098	1201
Below Balvaar	308	306	322	329
Balvaar, Top Ridge	401	449	473	490
Balvaar to Cairn	549	562	589	599
The Cairn	2703	2749	2783	2899
Cairn to Mare	688	726	731	783
Barrheads	2457	2498	2523	2508
Above Black Holes	413	452	439	467
Mare	4306	4301	4318	4292
Mare, Lower Ledge	188	191	190	187
Above Bed o' Grass	303	322	341	352
Mare-Stranny Point, S1	596	593	602	628
Mare-Stranny Point, S2	614	648	639	686
Mare-Stranny Point, S3	841	893	931	940
Mare-Stranny Point, S4	942	985	997	1013
Stranny Point, South Side	48	50	52	51
Main Craigs, Main Part	1303	1396	1403	1439
Main Craigs, Top	1499	1573	1555	1589
Main Craigs, East	426	481	478	489
Main Craigs, East Top	89	111	103	107
Main Craigs, Far East	-	-	-	-
Main Craigs, Far East Top	47	59	53	55
Grand Total:	21997	22811	23042	23611

annual count is now virtually the same as the index of room, as one would expect.

Future Work

In this respect it should be clearly stated that, with the increasing size and complexity of the Gannet colony, the counting method used - even such a precise method as direct counts of occupied nests under rigidly controlled conditions - is now approaching the limits of its possible accuracy, even for myself with nearly 45 years' experience of annual comparative counts, so that if the spread of the Gannet colony continues, with the consequent areas of 'dead' ground which are difficult to count, then the annual census will no longer be able to provide the same degree of accurate comparison.

Previous Work

Direct counts of all occupied nests have now been carried out at the Ailsa Craig Gannet colony for nearly half a century. This work commenced in 1936, with a pioneer count by H.G. Vevers and James Fisher, and since the war years, when only curtailed counts and estimates of population could be used, I have continued the annual census without a break. For health reasons, however, it is now likely that I shall have to cease making the annual Gannet census in the fairly near future.

A comprehensive bibliography of all past census work was given in the last report (Gibson 1987b). It is not necessary to repeat this here, so the references given below cover the last five years, up to the present day.

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Dr. J.A. Gibson, Foremount House, KILBARCHAN, Renfrewshire PA10 2EZ.

AGE STRUCTURE AND GROWTH IN SCOTTISH POPULATIONS OF THE THREE-SPINED STICKLEBACK

By A.A. UKEGBU and F.A. HUNTINGFORD
Department of Zoology, University of Glasgow

Introduction

The Three-spined Stickleback *Gasterosteus aculeatus* has a highly variable age structure, coming to reproductive maturity at an age of either one or two years and with maximum reported life span in natural populations ranging from just over one year to four years. For example, most of the sticklebacks from the River Birket (Cheshire, England) breed in their second summer of life when about one year old and live for up to four years (Jones and Hynes 1950), as do those from the Priddy Pool, Dorset (Pennycuick, 1971). Sticklebacks from two lakes (Bare Lake and Karluk Lake) in Alaska, and from a site near Cambridge, England, first breed when one or two years old and have a life span of over two years (Greenbank and Nelson 1959, Craig-Bennett 1931). In contrast to these cases where sticklebacks live for more than one year, populations from two streams in southern England (Mann 1971) and from Llyn Frongoch in North Wales (Allen and Wootton 1982) are annual. Most of these fish breed in their second summer of life and few survive to an age of more than one year.

The causes of this variation are unknown, but Wootton (1984) has suggested that sticklebacks from more southerly populations may mature earlier and live less long than their northern counterparts. However, small-scale sampling from several sites in the environs of Glasgow suggest that sticklebacks from these more northerly sites are annual (Giles 1981 and 1987). Growth rates are also variable, even between populations with a broadly similar age structure; for example, by their first April sticklebacks from two annual populations in southern England grow to about 44mm (Mann 1971, cited in Wootton 1984), while at the same age those from Llyn Frongoch in mid-Wales only measure about 30mm (Wootton 1984).

The aim of the present study is to extend these observations, providing additional information on age structure, growth patterns, and age of maturation in populations of freshwater Three-spined Sticklebacks from Scottish populations.

Material and Methods

STUDY SITES AND SAMPLING REGIME

The data presented in this paper consist mainly of samples taken from three sites in the Glasgow area, namely the River Kelvin (4°8'W, 55°57'N; NS67), the River Luggie (4°10'W, 55°57'N; NS67) and the Aurs Burn (4°20'W, 55°48'N; NS55). The River Luggie is one of the sites sampled by Giles; the others are included for comparison, all being relatively fast-flowing urban streams. The sticklebacks were caught by means of a large hand net, care being taken to collect fish from different parts of the habitat. In the first year of the study (October 1982 to August 1983), twenty fish were sampled in each month; from September 1983 to August 1984 monthly samples of approximately 200 fish were collected from each site, although temporary lack of field assistance prevented any collections being made from the River Luggie or the Aurs Burn during Junē 1984. These fish were measured and assigned to size categories (see below).

A sub-sample of twenty sticklebacks, including a range of fish from within each size class, was returned to the laboratory where they were killed using benzocaine or MS222 anaesthesia, weighed (to the nearest mg) and used for further studies, including otolith analysis and assessment of reproductive status. In order to determine the fate of fry hatched at different times (see below), young of the year were collected at various points in the breeding season of 1983, maintained in large outdoor tanks and monitored for signs of breeding activity.

In addition to the three main sampling programmes, 100 fish were collected from Loch an Duin in North Uist, Outer Hebrides (7°10'W, 57°38'N; NF87) in early May 1986, just before the start of the breeding season, and were maintained in the laboratory for a further month to assess the reproductive status of the fish. Information on this very restricted study is presented here for the purpose of comparison.

GONADAL ANALYSIS

The gonads were dissected from the body cavity, fixed in 10% formalin, sectioned at 7μ and stained in haemalum and eosin. Developmental state of the ovary was assessed by classifying the ova according to size, nuclear condition and yolk deposition (Tromp-Blum 1959). The testes were screened for the presence of spermatogonia, spermatocytes, spermatids and spermatozoa (see Borg 1982).

AGEING THE FISH

The age-structure at the three main study sites was estimated on the basis of length-frequency histograms and otolith analysis, together with an assessment of gonadal state when the first two techniques gave conflicting answers. Both methods have their limitations (Wootton 1984): there is considerable overlap in size between age categories (Jones and Hynes 1950), but otolith annulations cannot always be related to seasonal growth patterns (Mullen and Vlugt 1964). However, a reliable estimate of the overall age structure of a population can be gained by a combination of these two methods (Mann 1971, Allen and Wootton 1982), even if individual fish cannot be aged unambiguously.

Standard lengths were measured to the nearest 1mm and, for the purpose of length-frequency analysis, the fish were assigned to 5mm size categories ranging from 16mm-20mm (category 1) to 56mm-60mm (category 9). To extract the otoliths, the top of the cranium was removed with a sharp scalpel, the cut extending from the back of the skull to the back of the eye. Any remaining part of the *medulla oblongata* was removed to expose the two sagittae, which were then picked out with fine forceps. The two sagittae were washed in distilled water, dehydrated in absolute alcohol for 30 minutes and then transferred to pure creosote oil for 10 to 15 minutes. Once cleared, they were mounted on a glass slide using DPX and examined with reflected light against a black background, at a magnification of x40.

A number of difficulties were encountered in interpreting the otoliths. Some very large fish (60mm and above) had otoliths with no clear annulations at all, even although their size compared to the rest of the population suggested that they were at least two years old; 3% of all the otoliths sampled fell into this category. In 1% of cases the pattern of annulation was different in the left and right otoliths, usually because one had many apparently false annulations. In such cases, one otolith was appropriate for the length of fish concerned and this was used in the analysis. In about 2% of cases, a relatively big fish had fewer rings than would be expected, given its size. If this occurred during or immediately after the breeding season, histological analysis of the gonads indicated whether the fish was in breeding condition or had bred, and was therefore an adult rather than young of the year. Finally, in a further 2% of cases, otoliths suggesting an adult were found in relatively small fish. In these cases, the presence of immature gonads would indicate that the fish were young of the year. Altogether, ages

determined by otolith analysis and length class agreed well; using other criteria, such as gonad condition where necessary, 97% of all the fish could be aged with a high degree of confidence. The remaining fish were omitted from the analysis.

DATA ANALYSIS

Length distributions were studied by plotting the percentage of each month's sample which fell into each size category; the median and range of the lengths and weight of the fish in each sample which were assigned to specific age classes were used to investigate seasonal changes in size; differences in length and weight between each of the three main study populations were investigated by means of an Anova, carried out on male and female fish separately.

Results

LENGTH FREQUENCY DISTRIBUTIONS

Main Study Populations

Figures 1-3 show the length frequency distributions for the three main study populations. In all three the distribution is unimodal for most of the year, dominated by fish bred in the previous breeding season. The distribution becomes bimodal in the summer months as young of the year are recruited into the population. By November the length frequency histogram has become unimodal again in all three populations as the few surviving adults die out during the winter. These distributions indicate that very few fish (and these are mostly females) survive to an age of two years. The results of the smaller scale study in 1982-1983 were similar.

Fish of less than 20mm were still found in all populations in August and September. Breeding males were still seen tending nests at this time, so at least some of these small fish were late-hatched fry rather than slow-growing fry of earlier broods. This suggests that sticklebacks from these populations have a more protracted breeding season than is commonly reported. The tail of late-hatched fry was seen in both the 1983 and 1984 breeding seasons. In the autumn, the same cohort contained fish ranging in length from less than 20mm (weighing as little as 0.16gm) to 45mm (weighing up to 1.30gm). By the following spring, some fish caught in the wild were still considerably smaller than their contemporaries. Most of these small fish failed to reach reproductive maturity at the start of the breeding season. To give an example, in May 1984 the largest female of the 1983 cohort from the River Kelvin measured 56mm, weighed 2.34gm and had an ovary full of mature

ova; the smallest was 36mm long, weighed 0.59gm and had no ova in which yolk deposition had commenced. The largest male was 54mm, weighed 2.04gm and had only spermatids and spermatozoa in his testis, compared to the smallest (37mm, 0.62gm), whose testis contained predominantly spermatocytes.

In July some females of the 1983 cohort from the River Kelvin still measured only 40mm (weight 2.04gm) and had no ova in which the final stages of yolk deposition had begun; males were still found (at 41mm and 0.79gm) with only spermatocytes and spermatogonia in their testes. Thus sticklebacks which are small in their first autumn of life (in some cases at least because they hatched late) may fail to breed at all in their second summer of life. This is true both of wild-caught fish and of late-hatched fry housed in large outdoor tanks on a good food supply. Since very few sticklebacks from the three study sites survived to the following year, this means that a proportion of fry hatched late in the season did not breed at all.

North Uist Sticklebacks

Figure 4 shows length frequency histograms for the fish from Loch an Duin, North Uist. In May, when the fish were collected, the distribution was bimodal, and since the breeding season had not started at this time, the population would seem to consist of both one-year old fish (with a modal length of 30mm-35mm) and two-year olds (modal length 40mm-45mm). Many of the fish (both males and females) from the two size modes came into breeding condition the following month, although a small group of non-breeding fish was found. The data suggest that sticklebacks from this population can survive for two years and that breeding fish may be either one year or two years of age.

OTOLITH ANALYSIS

The otoliths of sticklebacks in the summer of hatching have a centre (C) and an opaque ring (O). A transparent ring (T) is then added, following which alternating opaque and transparent rings appear as the fish age. Five categories of otolith were recognised on the basis of these patterns of annulation, and the occurrence of fish in the various categories in the three study populations is shown in Table 1. Although the patterns of ring formation are broadly similar for the three main study populations, the time at which these are laid down and the length at which these occur vary both within and between populations. All young fish caught in their first summer of life had a centre and an opaque ring. In fish from the River Kelvin, a transparent ring was added in some fish as

Figure 1

Length-frequency histograms for the monthly samples of sticklebacks from the River Kelvin

Size Categories

1 15-20 mm
2 21-25 mm
3 26-30 mm
4 31-35 mm
5 36-40 mm
6 41-45 mm
7 46-50 mm
8 51-55 mm
9 56-60 mm
10 61-65 mm

River Kelvin

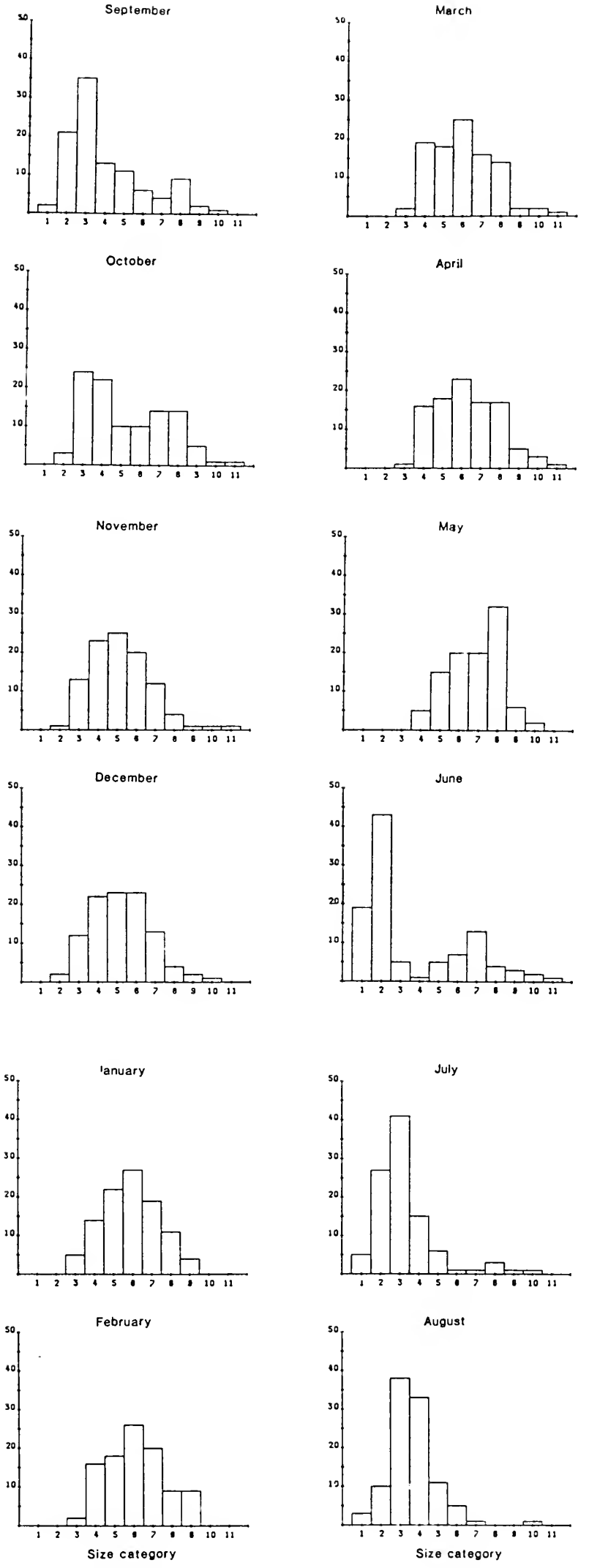

September
March
October
April
November
May
December
June
January
July
February
August
Size category
Size category

Figure 2

Length-frequency histograms for the monthly samples of sticklebacks from the River Luggie

Size Categories

1 15-20 mm
2 21-25 mm
3 26-30 mm
4 31-35 mm
5 36-40 mm
6 41-45 mm
7 46-50 mm
8 51-55 mm
9 56-60 mm
10 61-65 mm

River Luggie

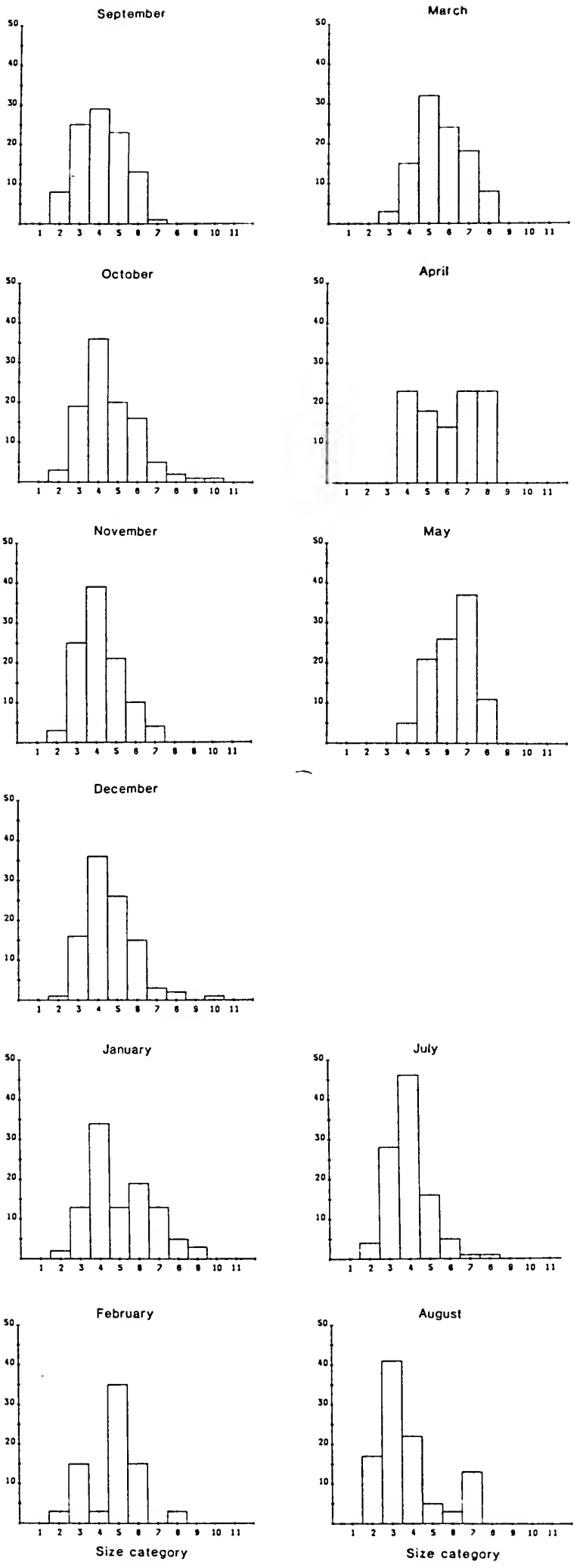

September
March
October
April
November
May
December
January
July
February
August
Size category
Size category

Figure 3

Length-frequency histograms for the monthly samples of sticklebacks from the Aurs Burn

Size Categories

1 15-20 mm
2 21-25 mm
3 26-30 mm
4 31-35 mm
5 36-40 mm
6 41-45 mm
7 46-50 mm
8 51-55 mm
9 65-70 mm
10 61-65 mm

Aurs Burn

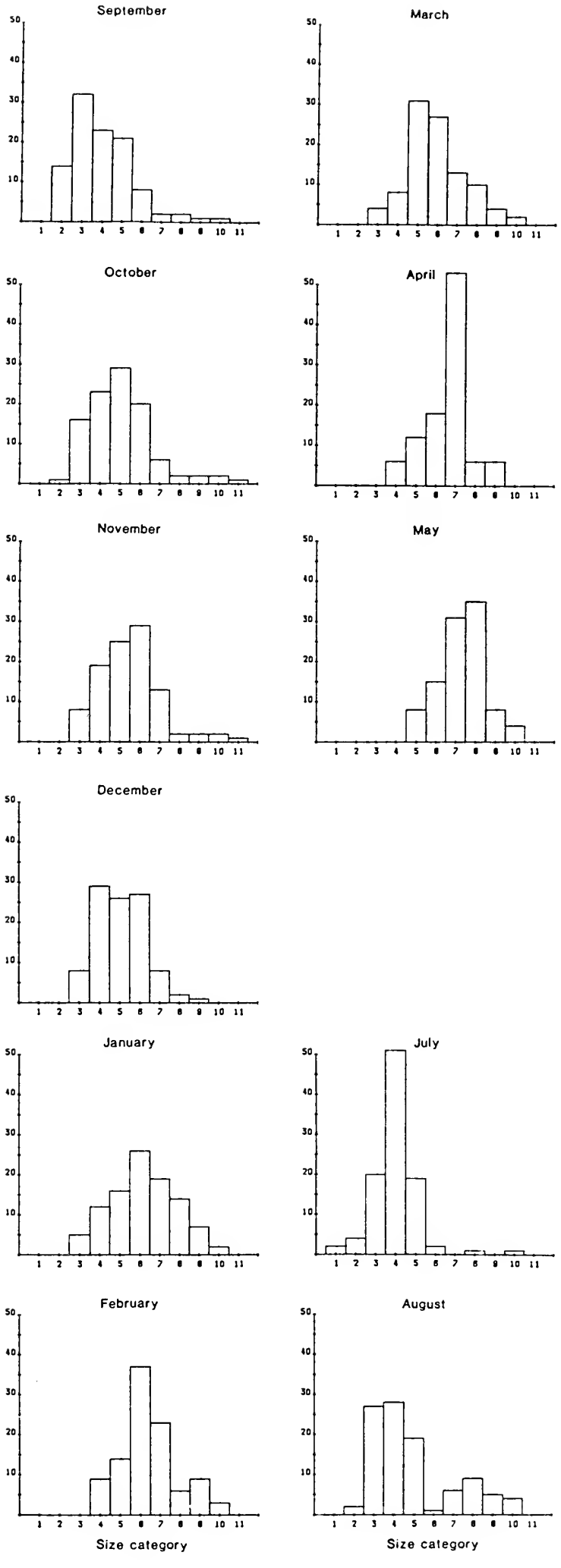

September
March
October
April
November
May
December
January
July
February
August
Size category
Size category

Figure 4

Length-frequency histograms for one sample of sticklebacks collected from Loch an Duin, North Uist in May 1986 and maintained in the laboratory for a further month

Size Categories

1 51-20 mm
2 21-25 mm
3 26-30 mm
4 31-35 mm
5 36-40 mm
6 41-45 mm
7 46-50 mm
8 51-55 mm
9 56-60 mm
10 61-65 mm

Loch an Duin

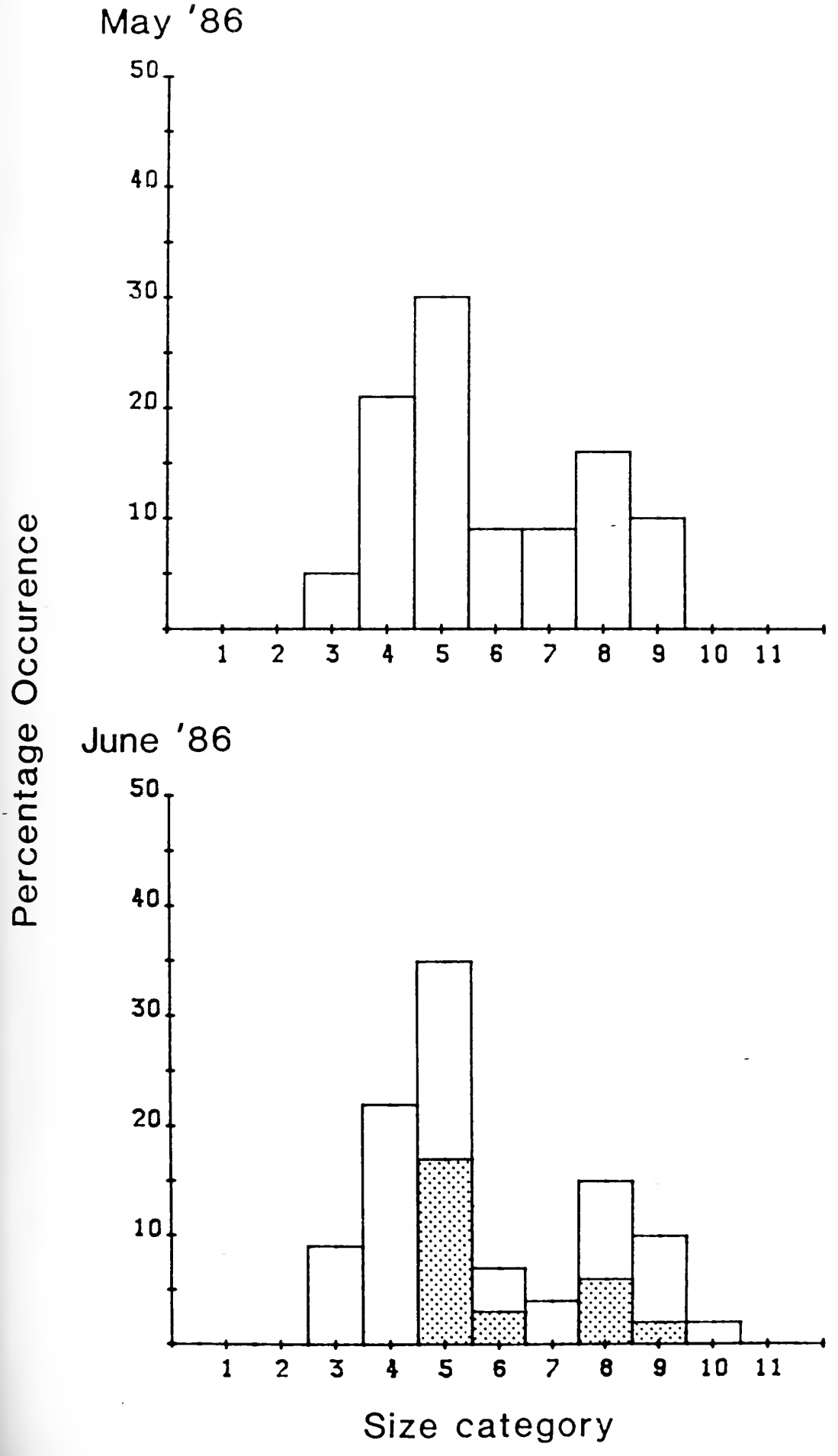

May '86
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11
June '86
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11
Percentage Occurence
Size category

Table 1

Frequency distribution of otolith types, with mean and range of standard length of the fish in each category

K - River Kelvin

L - River Luggie

A - Aurs Burn

		Otolith Category				
		CO	COT	COTO	COTOT	COTOTO
K	September 1983	24	38	10	28	-
	October 1983	-	72	4	24	-
	November 1983	-	85	-	15	-
	December 1983	-	90	-	11	-
	January 1984	-	95	-	5	-
	February 1984	5	95	-	-	-
	March 1984	-	95	5	-	-
	April 1984	5	85	5	5	-
	May 1984	-	91	10	-	-
	June 1984	25	55	15	-	5
	July 1984	52	22	26	-	-
	August 1984	30	65	5	-	-
	Mean Standard Length (mm)	31	40	44	52	61
	Range (mm)	2.2-5.1	2.8-4.6	3.6-4.4	5.0-6.0	-
L	September 1983	-	20	-	-	-
	October 1983	-	-	-	-	-
	November 1983	15	85	-	-	-
	December 1983	-	84	-	16	-
	January 1984	32	63	-	5	-
	February 1984	5	95	-	-	-
	March 1984	-	100	-	-	-
	April 1984	-	100	-	-	-
	May 1984	-	68	32	-	-
	June 1984					
	July 1984	85	5	10	-	-
	August 1984	60	40	-	-	-
	Mean Standard Length (mm)	32	36	41	55	-
	Range (mm)	29-40	20-44	38-46	55-56	-
A	September 1983	73	15	8	4	-
	October 1983	-	72	-	28	-
	November 1983	-	100	-	-	-
	December 1983	5	89	-	-	-
	January 1984	50	44	6	-	-
	February 1984	25	70	-	-	-
	March 1984	25	75	-	-	-
	April 1984	6	94	-	-	-
	May 1984	10	85	5	-	-
	June 1984					
	July 1984	90	10	-	-	-
	August 1984	65	20	15	-	-
	Mean Standard Length (mm)	33	40	47	56	-
	Range (mm)	23-46	27-49	47-51	51-59	-

early as July (in fish ranging in length from 28mm to 38mm). This transparent ring was first observed in fry from the River Luggie (in fish from 20mm to 38mm) and from the Aurs Burn (in 27mm to 42mm fish) in September. Fish of the 1983 cohort were still found with the configuration CO in the River Luggie in February (in a 38mm fish), in the River Kelvin in April (in one fish of 51mm) and in the Aurs Burn in May (in fish of 31mm and 46mm).

The second opaque ring was first seen in River Kelvin fish in March (in one fish of 36mm), but sticklebacks from the two other sites first laid down this second opaque ring in May (in fish from 35mm-42mm in the Luggie and in one 47mm fish from the Aurs Burn). A second transparent ring was seen in September in fish from the River Kelvin (at 48mm-56mm) and from the Aurs Burn (51mm), and in October in Luggie fish (at 55mm). Only one fish was found with a third opaque ring, a 61mm female from the River Kelvin caught in June, at an age of two years. The oldest fish from the River Luggie and the Aurs Burn (both females and with the configuration COTOT) were caught in January and February and measured 55mm and 59mm respectively, with an age of approximately 18 months.

GROWTH RATES

Figure 5 shows the median and range of the length of fish assigned to the various age classes for each monthly sample for the three populations. Figure 6 shows the median and range of the weights of the 1983 cohort from the subsamples brought into the laboratory, with data combined into two-month blocks to increase sample sizes. On the assumption that the populations were sampled at random with respect to size, and that mortality is not size-dependent, these changes reflect the pattern of growth in the subjects. Immediately after hatching, growth is rapid, but this levels off to a fairly steady rate, with something of a plateau in length between the months of December and March and a decrease in weight. The fish from the River Kelvin, Aurs Burn and River Luggie reached an average length of 40mm, 41mm and 39mm respectively by the April of their first spring, with weights of 1.2gm, 0.99gm and 0.78gm. By the end of their second summer (in August) they measured 46mm, 52mm and 43mm and weighed 1.27gm, 1.32gm and 1.20gm. The largest fish in the three study populations were all female and were all without distinguishable annulations in their otoliths; their lengths were 68mm for the Kelvin (caught in June, weighing 4.38gm and almost certainly two years old), 65mm for the Aurs Burn (caught in November, weighing 2.78gm and probably just

over two years) and 59mm for the Luggie (caught in October at about 15 months and weighing 2.5gm). From an early stage (see Figure 4, Figure 5, and Table 2), both male and female sticklebacks from the River Luggie were significantly shorter and lighter ($p<0.01$) than their contemporaries from the Aurs Burn, with Kelvin fish being largest of all.

Discussion

Broadly speaking, longer sticklebacks have more otolith rings, but there is considerable variation, both within and between populations, in the age and size at which the rings are laid down; as a result, extensive size overlap exists between otolith types. Sticklebacks from the River Kelvin, which are larger than their contemporaries, consistently lay down the various rings earlier than those from the other two sites. The timing of ring formation seen in this study agrees in general with that observed by Allen and Wootton (1982) for sticklebacks from Llyn Frongoch, North Wales, although in the latter case all the fish had a transparent ring by October of the year in which they were bred, even although their growth rates were slow.

The length frequency distributions and otolith analyses used to age sticklebacks in this study agree with each other. A clear picture of the age structure of the three main study populations was obtained. Both sources of evidence show that all three populations are annual, the great majority of fish living for just over a year and with a maximum life span of 18-24 months (depending on site) attained by a very few fish, all female. This agrees with observations, in the field and in the laboratory, of mass mortality in adult sticklebacks, particularly males, from all three study sites shortly after the breeding season. Giles (1981) also found that the stickleback population in the River Luggie was annual, and these observations agree with several reports for other populations (Allen and Wootton 1982, Greenbank and Nelson 1959, Mann 1971). In contrast, the sticklebacks collected from North Uist seem to be biannual, agreeing with Wootton's (1984) suggestion that more northerly populations may live longer. At least some of these fish, however, breed at one year of age, even although they may be less than 35mm long.

In all three mainland study populations, breeding commences in late April or early May and may continue well into August; for North Uist sticklebacks the breeding season starts somewhat later. The young fish grow fast in their first months of life, but growth slows down during the winter. By April many fish attain maturity and breed. This pattern of growth is

Figure 5

Median and range of the length (mm) of sticklebacks in each age class of the monthly samples from the three main study sites

River Kelvin

River Luggie

Aurs Burn

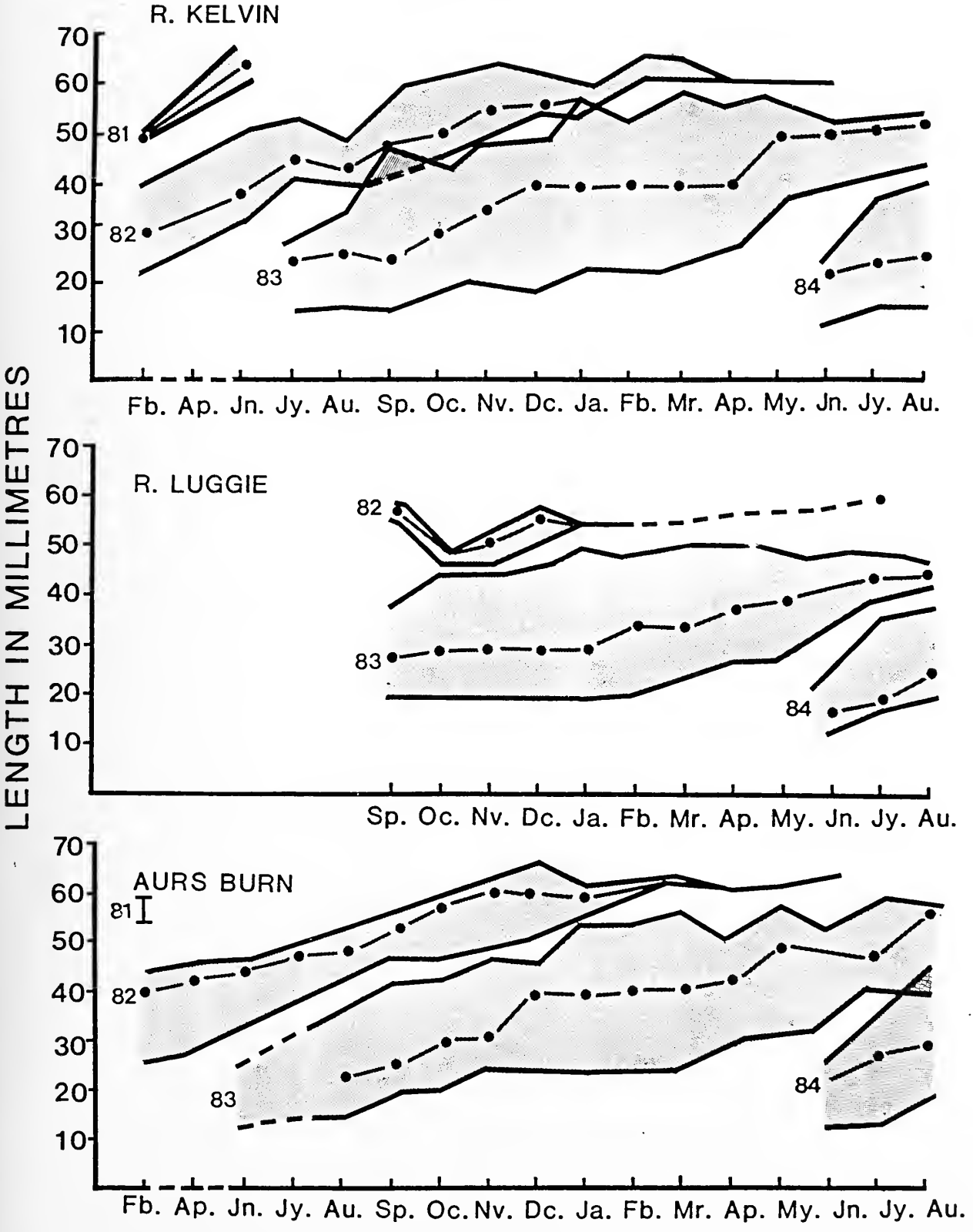

R. KELVIN
70
60
50
40
30
20
10
81
82
83
84
Fb. Ap. Jn. Jy. Au. Sp. Oc. Nv. Dc. Ja. Fb. Mr. Ap. My. Jn. Jy. Au.
LENGTH IN MILLIMETRES
R. LUGGIE
82
83
84
Sp. Oc. Nv. Dc. Ja. Fb. Mr. Ap. My. Jn. Jy. Au.
AURS BURN
81
82
83
84
Fb. Ap. Jn. Jy. Au. Sp. Oc. Nv. Dc. Ja. Fb. Mr. Ap. My. Jn. Jy. Au.

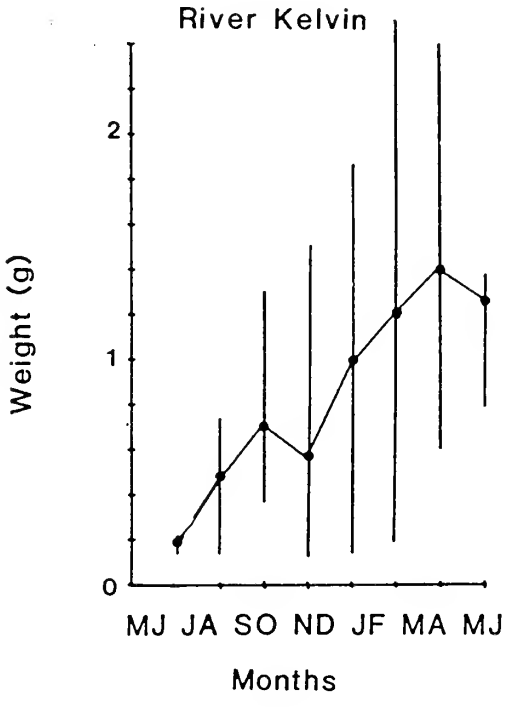
Figure 6

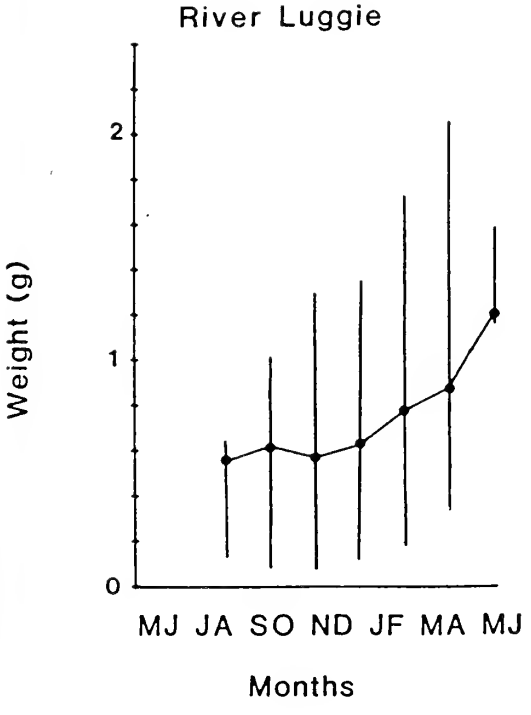
Median and range of the weight (gm) (combined into two-month blocks) of sticklebacks in the 1983 cohort age class from monthly sub-samples from the three main study sites

River Kelvin

River Luggie

Aurs Burn


River Kelvin
Weight (g)
0
1
2
MJ JA SO ND JF MA MJ
Months


River Luggie
Weight (g)
0
1
2
MJ JA SO ND JF MA MJ
Months

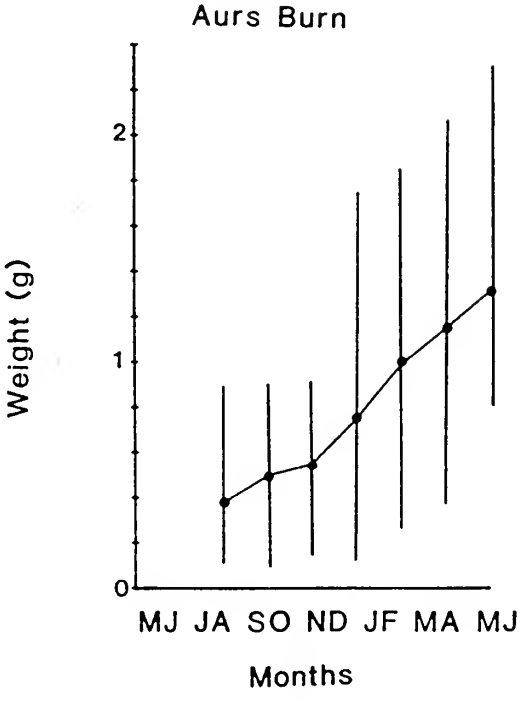

Aurs Burn
Weight (g)
0
1
2
MJ JA SO ND JF MA MJ
Months

Table 2

Mean and standard error of lengths (mm) and weights (gm) of male and female sticklebacks from the three study sites

		KELVIN		LUGGIE		AURS
LENGTH	Females	42.6 ± 0.8	<-*->	36.7 ± 0.9	<-*->	40.9 ± 0.9
	Males	41.4 ± 0.7	<-*->	38.8 ± 0.7		40.1 ± 0.6
WEIGHT	Females	1.09 ± 0.06	<-*->	0.76 ± 0.06	<-*->	0.96 ± 0.06
	Males	0.95 ± 0.04	<-*->	0.82 ± 0.05		0.80 ± 0.04

* Represents differences signification $p<0.01$

similar to that observed in other studies; growth rates (both in length and in weight) are comparable to those reported for freshwater ('leiurus') sticklebacks from southern England by Mann (1971) (see Wootton 1984), but fish from Llyn Frongoch do not attain a comparable length until they are fifteen months old (Allen and Wootton 1982).

The slow growth rate of Llyn Frongoch sticklebacks was ascribed to poor food supply (Allen and Wootton 1982). In the present study, fish from the River Luggie were shorter than those from the other two sites from an early age; from January onwards they were also lighter. Sticklebacks from the River Kelvin were the largest of all. This, too, may reflect differences in diet; stomach analyses suggest that, in the River Luggie, copepods, a profitable food for small sticklebacks (Ibrahim, unpublished data), are rare or inaccessible, so the young fish eat larger, less profitable, Crustacea such as *Asellus*. On the other hand, even large sticklebacks from the Aurs Burn take few *Asellus*, a profitable prey type for larger fish (Ibrahim unpublished data, Ukegbu 1986, Ukegbu and Huntingford 1988a). Both food types seem to be available to sticklebacks in the River Kelvin.

Within a single cohort, variation in size is considerable and many fish from later broods are still less than 30mm in length at the beginning of the breeding season. These fish do not have mature gonads, and although some grow large enough to breed later in the season, others do not breed at all in their first full summer of life. Allen (1982) also noted some fish which did not breed in the first breeding season after hatching, possibly as a result of small size, parasite load or food shortage. These sticklebacks which failed to breed in their first full summer could potentially survive to breed for the first time in the next breeding season at an age of about twenty months. Allen suggests that this may be the case for sticklebacks from Llyn Frongoch. However, for sticklebacks from the mainland sites of the present study, survival to a second breeding season is rare in females and never occurs in males. So the chances that fry hatched late in the season will breed at all are fairly slim. As a consequence, broods produced late in the season are less valuable in terms of expected reproductive output than those produced at the start of the season, and this has implications for the parental investment they receive (Ukegbu 1986, Ukegbu and Huntingford 1988b).

Summary

This paper describes the results of an intensive sampling programme carried out over a two-year period on three

populations of Three-spined Sticklebacks from south-west Scotland, and a much smaller scale study of a population in North Uist, Outer Hebrides. Both length frequency studies and otolith analysis suggest that the three mainland sites are annual, with a very few fish (all female) surviving for more than one breeding season. In contrast, the length distributions in the North Uist fish just prior to and during the breeding season suggest that this is a biannual population, with both males and females breeding at one and two years of age. The breeding season for the mainland fish is somewhat more protracted than has been reported elsewhere. Growth rates are comparable to those described for a number of other populations, but a significant proportion of fish (probably those hatched late in the season) fail to grow to a sufficient size to breed in their first summer. Because almost no fish from the mainland study sites survive to breed at two years, these slow-growing, late-hatched fish often fail to breed at all.

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Dr. Angela A. Ukegbu, Department of Zoology, University of Glasgow, GLASGOW G12 8QQ.

Dr. Felicity A. Huntingford, Department of Zoology, University of Glasgow, GLASGOW G12 8QQ.

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LOCHS OF THE SCOTTISH BORDERS REGION: AN ECOLOGICAL STUDY

By DAVID H. JONES
Institute of Terrestrial Ecology, Edinburgh

Abstract

Between 1983 and 1986 nineteen lochs from diverse habitats in the Scottish Borders Region were sampled for crustacean zooplankton and inshore benthic microfauna. Water samples were taken to measure selected chemical parameters (e.g. pH, silica and phosphorus). Wide diversity in some measurements and in the species assemblages of some sites was noted. Relationships between physical, chemical and biological parameters have been investigated. Grouping of the sites by similarities in their physical conditions and land-use characteristics was not always mirrored by the microfauna, and some anomalies were noted. Several sites were chemically enriched, some possibly due to agricultural or forestry practices, others almost certainly due to large flocks of roosting birds. The physical nature and increased biological productivity due to chemical enrichment may be hastening the evolution and disappearance of many small lochs.

Introduction

The Scottish Borders Region covers 467,158 hectares of very varied land (Figures 1 and 2) from the easternmost end of the Southern Uplands (c. 800 metres above sea level) to the North Sea coast of Berwickshire. The source and the main catchment area of the River Tweed lie in the hills of the western part and, after flowing through the low-lying and rich agricultural land of the Merse, the river discharges into the sea at Berwick-on-Tweed. Major tributaries include the Ettrick, Teviot, Till and Whiteadder as well as a number of lesser streams.

Standing water bodies are numerous throughout the whole area and many of them are relatively small and shallow. Three hundred and twenty such waters were noted on the 1961-63 revision of the 1:63360 Ordnance Survey maps (C.O. Badenoch, pers. comm.), but with the exception of two surveys, each initiated by the Nature Conservancy Council, on St. Mary's loch (Maitland and Morris, 1979) and Lindean Reservoir (Maitland *et al.*, 1980), little limnological information for the area has been discovered, and, in view of present-day pressures upon such small water bodies, their status may well be changing.

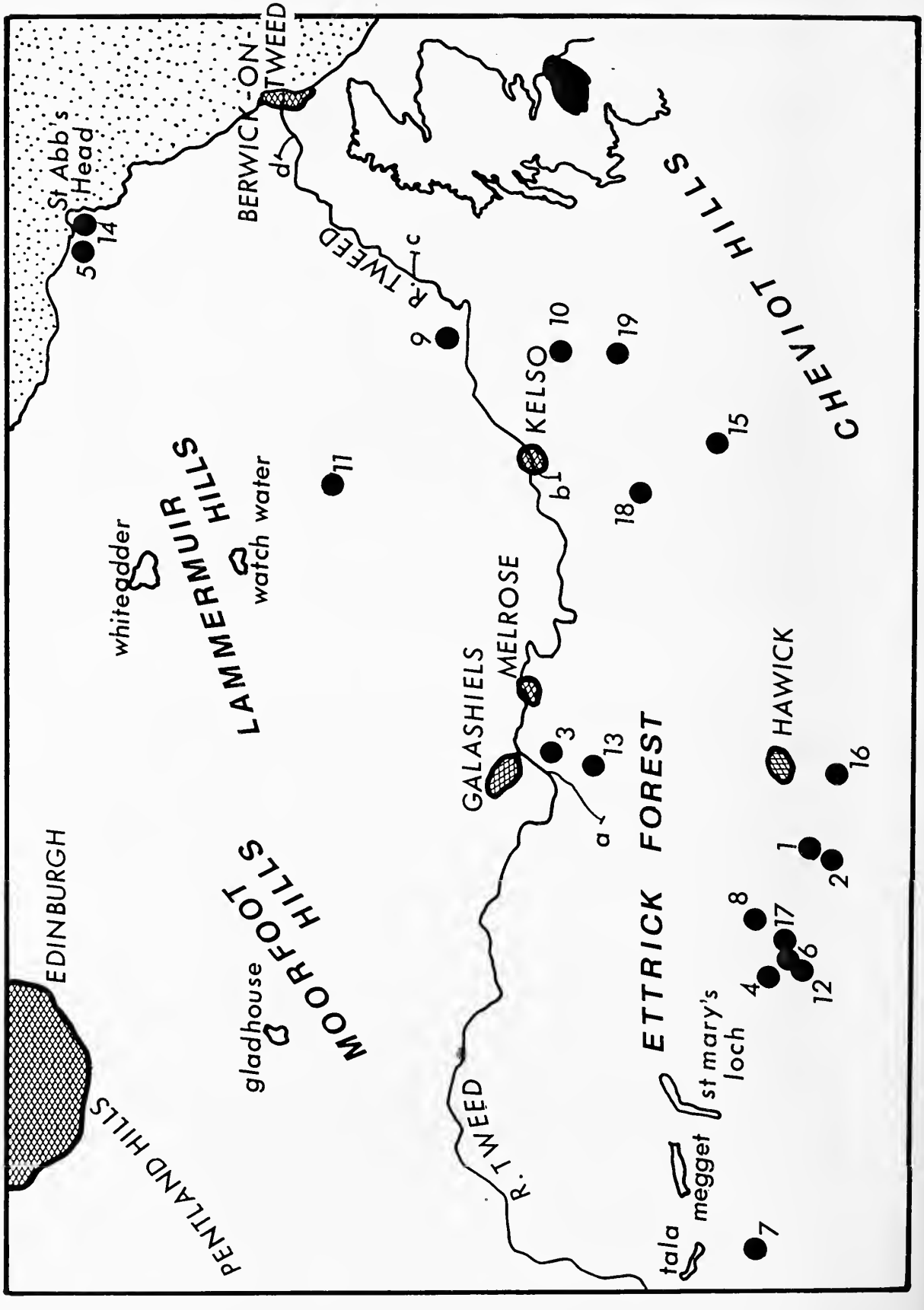
St Abb's Head
14
5
BERWICK-ON-TWEED
d
R. TWEED
c
9
10
KELSO
b
19
15
CHEVIOT HILLS
whitegadder
watch water
LAMMERMUIR HILLS
11
18
GALASHIELS
MELROSE
3
13
a
HAWICK
16
EDINBURGH
MOORFOOT HILLS
gladhouse
ETTRICK FOREST
1
2
8
17
6
4
12
st mary's loch
PENTLAND HILLS
R. TWEED
megget
tala
7

Figure 1

Map of S.E. Scotland showing the position of the nineteen sampling sites, the River Tweed, its principle tributaries, the major water bodies and the main urban centres of the area. The hills of the Borders Region and adjacent areas are identified.

The geographical location of the Region is indicated on the inset map.

a - Ettrick Water.

b - River Teviot.

c - River Till.

d - Whiteadder Water.

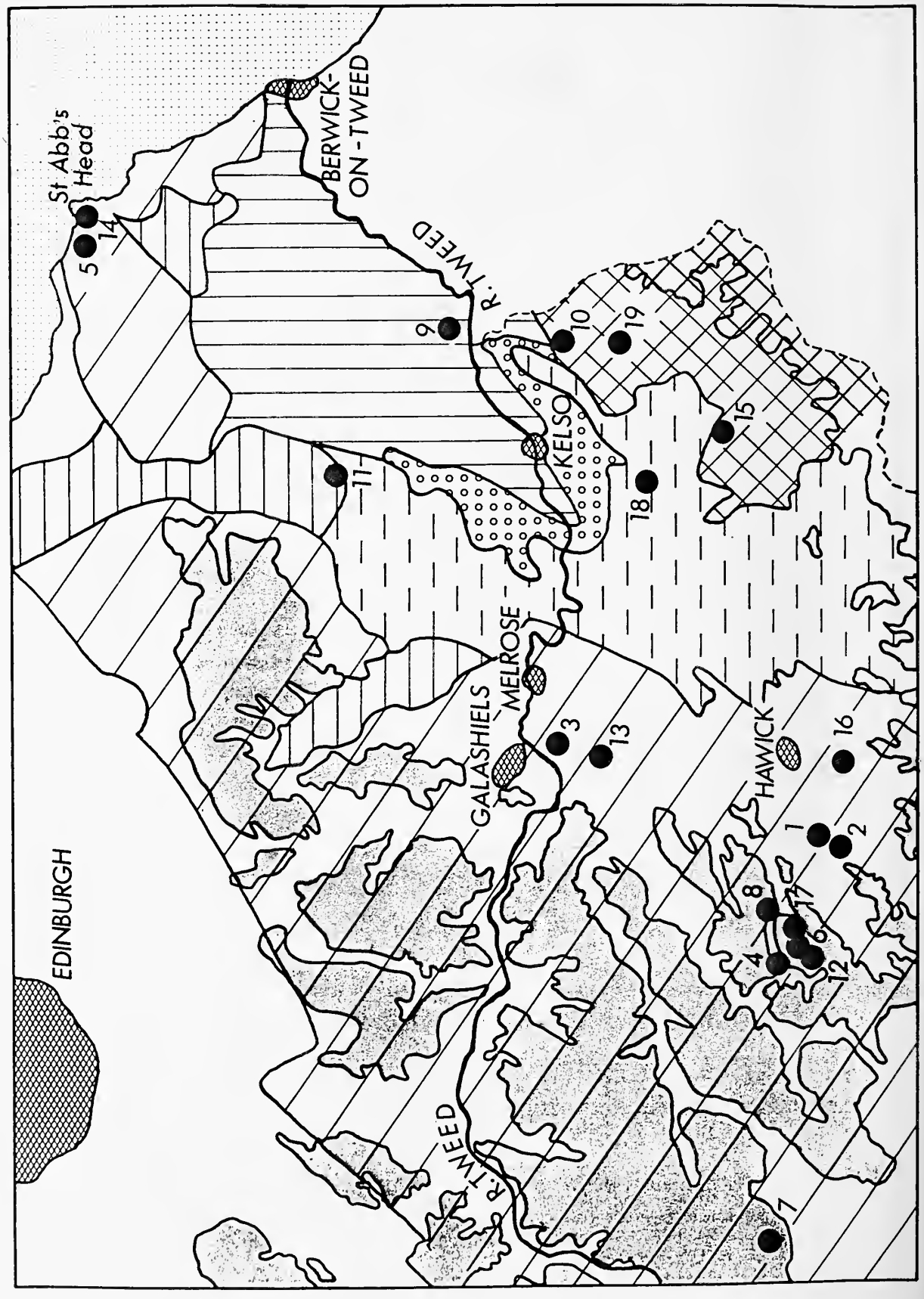
St Abb's Head
BERWICK-ON-TWEED
R. TWEED
KELSO
MELROSE
GALASHIELS
HAWICK
EDINBURGH
R. TWEED
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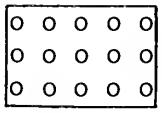
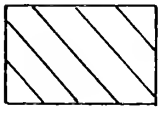
Figure 2

Map of S.E. Scotland showing the position of the nineteen sampling sites, the major geological divisions of the Region, and land over 1,000 feet (305 m.a.s.l.).

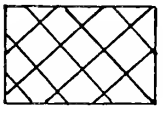


Basalt and Spilite

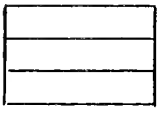
Carboniferous Limestone



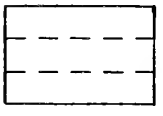
Ordovician and Silurian Greywackes and Shales



Andesitic and Basaltic Lavas and Tuffs



Lower Old Red Sandstone



Upper Old Red Sandstone

Uniform dark shading - Land over 1,000 feet (305 m.a.s.l.).

Partly because of this lack of information, an intensive survey of the phytoplankton periodicity and water chemistry of eight small lochs was initiated in 1983 (Bailey-Watts *et al*, 1987; Bailey-Watts and Kirika, in preparation). The study reported here developed from the above work, when samples from two sites were found to contain two species of Cladocera previously believed to be rare in Scotland (Harper, 1976; Jones, 1984a). Sampling was extended on an *ad hoc* basis, sites being added as time and facilities permitted. Coldingham Loch, one of the original eight sites, has been studied in much greater detail, regular sampling having been carried out for a number of years (Bailey-Watts *et al.*, 1987). Details of the sites are given in Table 1.

The Environment

HYDROLOGY

Most of the sub-catchments are small (<100 ha). Two exceptions are Yetholm Loch (428 ha) which lies close to the foothills of the Cheviots, and Clearburn loch (491 ha) above the Ettrick Water. A third loch, Williestruther, has an intermediate catchment of 189 ha. The inflows and outflows of many sites are insignificant and may be difficult to find. Some of the outflows are artificial and drain the loch some distance from the natural or original outflow. The history of individual lochs may be rather obscure, but actions such as draining, sediment removal for marling of clay land, peat-digging, damming and the subsequent raising of water levels, are known to have occurred in a number of instances. Only one site, the Hirsel Lake, is believed to have been constructed artificially, while a few sites, such as Gameshope and Coldingham, may be entirely natural. Inputs to these small lochs often depend mainly on seepage or general surface drainage from the surrounding land, especially at times of high rainfall.

The largest of the lochs, Hellmoor, has a surface area of only 25 ha, and the three smallest lochs are between one and two ha each. Despite the shallowness of most of the lochs (1-5 m) and because of their inflow/outflow regimes and small catchments, the residence times are believed to be quite long and losses of chemical inputs or organic materials may be slight. For example, the residence time for Coldingham Loch is estimated to be 3.2 years (Bailey-Watts *et al.*, 1987).

CATCHMENT GEOLOGY AND LAND USE

The Borders Region can be divided roughly into three areas, each with distinct geological characteristics (Figure 2). In the

Table 1. Grid references and physical data for nineteen Border lochs.

SITE	GRID REFERENCE	ALTITUDE M.a.s.l.	SURFACE AREA hectares	CATCHMENT AREA hectares
1. Branxholme E.	NT435118	270	6.2	48.9
2. Branxholme W.	NT422121	270	2.0	40.0
3. Cauldshiels	NT515322	240	9.0	34.0
4. Clearburn	NT341155	300	6.4	491.0
5. Coldingham	NT895685	135	8.6	45.0
6. Crooked	NT355140	350	4.7	34.1
7. Gameshope	NT130164	560	1.6	79.0
8. Hellmoor	NT389169	350	24.6	92.4
9. Hirsel	NT825402	25	12.7	30.0
10. Hoselaw	NT809319	180	11.2	46.5
11. Hule Moss	NT715491	235	6.7	25.0
12. Kingside	NT333135	360	6.7	60.0
13. Lindean	NT595294	260	7.1	85.0
14. Mire	NT915688	30	3.2	49.0
15. Whitton	NT746198	255	4.6	49.7
16. Williestruther	NT493115	205	5.1	189.3
17. Windylaw	NT361143	355	1.3	17.8
18. Wooden	NT708255	60	5.5	66.3
19. Yetholm	NT803283	107	16.8	428.1

western hilly region the rocks are mainly Ordovician and Silurian greywackes and shales. To the east of these, and particularly in the north of the Region, there is an area of Upper and Lower Old Red Sandstone, and included within it are intrusions and outcrops of igneous rocks such as basalt and dolerite. In the eastern central area, in the Merse, the rocks consist almost entirely of the Scottish Calciferous Sandstone series. There is therefore a trend from west to east (although not entirely clear-cut) of poorer more acidic soils on the higher ground to the west, and richer more alkaline soils to the east. This trend is paralleled not only by the altitude differences, but by differences in land use, where agricultural or forestry practices may considerably alter the natural conditions. The total area under forest cultivation in the Borders Region in 1980 was 65,930 ha (Borders Regional Council, 1986). Relatively new forestry and open moorland predominate on the mountains of the west; improved grazing is found high in the marginal zone, while richer grazing and arable farming predominate on the lower land and in the river valleys of the east (Figure 3).

Because of the generally high buffering capacity of many of the rocks in the Borders Region, the area is not considered to be at 'high risk' from acid deposition. According to the criteria given by the Department of the Environment (U.K. Acid Waters Review Group, 1986), it is judged that approximately a dozen of the surveyed sites are in a 'medium risk' area and the remainder in a 'low risk' area (see below).

CLIMATE, TEMPERATURE AND RAINFALL

The climate ranges from 'cold and wet' on the hills in the west, through 'warm and wet' on lower ground inland, to 'warm and moderately dry' in the coastal belt and lower Tweed valley (Birse and Dry, 1970). The 'growing season' (the period with a daily mean temperature of 5.6°C or above) varies between 150 days on the western hills to 219 days at Kelso, and may be as high as 250 days on the coastal plain. The average annual rainfall varies from c. 2,000 mm on the inland hills to between 600 mm and 800 mm nearer to the coast (Bown and Shipley, 1982).

Materials and Methods

CHEMISTRY

The following parameters were measured: pH, conductivity, phosphorus, silica and nitrogen. Sub-surface water samples were collected either by wading out into about one metre of water or by throwing out a self-filling sampling device to some 15 m from the shoreline. The methods used for analysis of the major

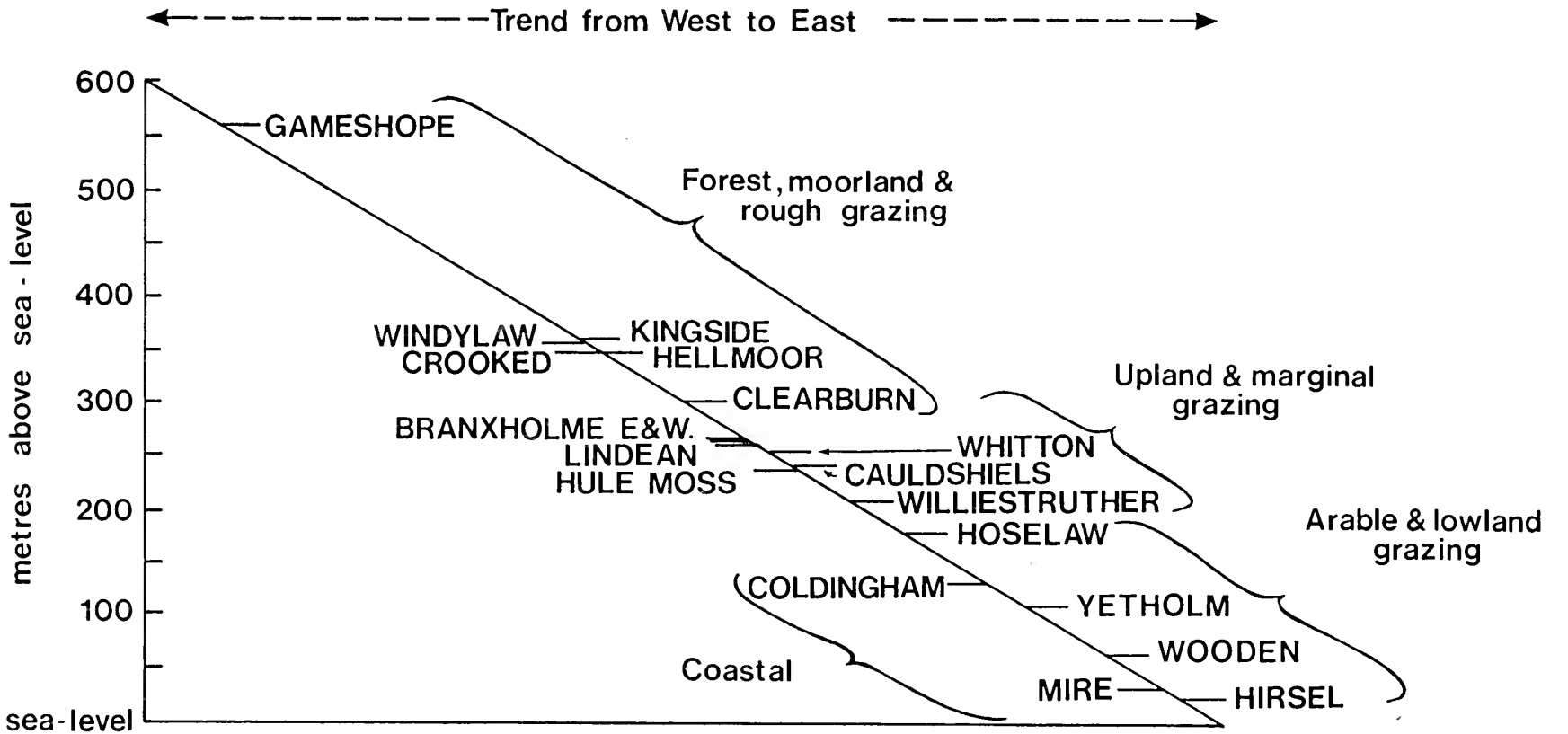


Figure 3

A diagrammatic representation of the 19 lochs arranged according to their altitudes. The principal land-use in their catchments is given in general terms.

parameters are given in Bailey-Watts *et al.* (1983). The pH value was usually measured on site using a Gallenkamp pH stick; conductivity was measured by a field meter. Other analyses were carried out on chilled samples, generally within 24 hours of collection.

BIOLOGY

Filtration of the water samples through glass-fibre filter pads (Whatman GF/C) provided samples of phytoplankton from which chlorophyll *a* was extracted by acetone and methanol (Bailey-Watts *et al.*, 1983). The concentration of chlorophyll *a* from a known volume of filtered water was calculated and used as a measure of phytoplankton abundance.

The microfauna was assessed by two methods:

1. Crustacean zooplankton was collected by throwing out a plastic sampling tube (26 cm long x 6 cm diameter) containing a removable nylon gauze filter (40 meshes/cm). The tube was attached by a bridle to a line marked at 0.5 m intervals. It was thrown out from the shore for c. 12-15 m and then hauled in, thus collecting a sub-surface sample of zooplankton. Two or three casts were made at each of two or three stations around the loch, and the material was bulked and stored in 4% formaldehyde.

2. Inshore epibenthic microfauna was collected at each site using a D-framed nylon gauze net (40 meshes/cm) on a pole. An area of substrate twice the area of the net mouth (22 cm x 19 cm), was lightly disturbed by a soft-bristled brush. The net was then swept in an arc, from the surface to just above the substrate and then up to the surface again. This sweep collected the fauna of the disturbed substrate, any organisms in the water column in the vicinity of the disturbed area, and the fauna associated with any macrophytes in the path of the net. At least one sweep, and usually two sweeps, were made at three or four stations in each loch.

For each type of sample the preserved material was either counted in its entirety, if there were less than c. 200 specimens, or was sub-sampled to provide approximately 200 specimens for identification. The results of these identifications and counts are expressed as a percentage of the recorded species assemblage.

Within the 'strenuus' group of *Cyclops*, morphological variation was noted and although most of the specimens were considered to be *Cyclops strenuus abyssorum*, material resembling *Cyclops vicinus* was found at some sites. According to the

criteria used by Harding and Smith (1974), *Cyclops vicinus* was positively identified from Coldingham Loch and it is possible that it may occur in small numbers in some other lowland survey sites. Problems of nomenclature with varieties of *Daphnia hyalina* are acknowledged (see Christie, 1983) but the material found in these Border lochs appears to be identical to the form referred to in other Scottish lochs as *D. hyalina* var. *lacustris* (Scourfield and Harding, 1966; Johnson and Walker, 1974; Maitland *et al.*, 1981; Jones, 1984b). It appears to be the commonest form of *Daphnia* in southern and central Scotland. Samples of *Bosmina* and *Ceriodaphnia* have been identified and in all sites apart from two, Windylaw and Gameshope, the former are all believed to be *B. longirostris*, while the latter have all been identified as *C. quadrangula*.

Results

A summary of the water chemistry and phytoplankton biomass (as measured by chlorophyll *a*) is given in Table 2. Figures 4-9 show the sites in their ranked positions for five chemical parameters and chlorophyll *a*. Table 3 lists both planktonic and epibenthic microcrustacea according to their presence or absence at each site, and shows the percentage relative abundance of the dominant planktonic species.

Figure 3 shows the relationship between sites and altitude, and the type of land use predominant in the catchment areas. Although the altitudinal distribution is almost continuous, apart from Gameshope loch, the sites appear to fall fairly naturally into three groups: (A) forest, moorland and rough grazing, (B) upland and marginal grazing, and (C) arable and lowland grazing, with two sites in the lowland group adjacent to the coast and therefore also exposed to some marine influence. Some correlation was expected between land use, altitude and water chemistry, and between these factors and the microcrustacean species assemblages within each group of sites.

The species assemblages in the majority of standing waters in Scotland are dominated by either the calanoid copepod *Diaptomus gracilis*, the cyclopoid *Cyclops strenuus abyssorum* or, at some seasons, by the cladoceran *Daphnia hyalina*. *Bosmina* spp., *Polyphemus pediculus* or *Ceriodaphnia quadrangula* can also be very abundant on some occasions (Maitland *et al.*, 1981; Jones, 1984b and 1985). These authors also found that *D. gracilis* was the most abundant species in oligo/mesostrophic waters, and that it was replaced by *Cyclops s. abyssorum* in meso/eutrophic waters. The species assemblages of the nineteen Border lochs were examined in relation to this premise.

Table 2. Environmental data from nineteen freshwater lochs in the Borders Region of Scotland, showing maximum, mean and minimum values for four chemical parameters, plus mean values for conductivity+ and chlorophyll *a*.

	Phosphorus as $\mu g/l^{-1}$ PO_4	Silica as mg/l^{-1} SiO_2	Nitrogen as mg/l^{-1} NO_3/N	pH	Conductivity in $\mu S/cm^{-1}$ at 25°C	Chlorophyll *a* as $\mu g/l^{-1}$
BRANXHOLME	19.3	3.13	1.07	7.9		
EASTER	17.1	1.57	0.27	7.5	149	4.6
	14.7	0.10	0.01	7.0		
BRANXHOLME	20.2	4.00	0.01	7.6		
WESTER	17.6	2.49	0.01	7.2	164	6.0
	15.5	0.80	0.01	6.8		
	58.0	1.90	0.33	9.0		
CAULDSHIELS	39.8	0.85	0.06	7.8	101	11.5
	18.6	0.07	0.01	6.0		
	20.1	0.67	-	6.9		
CLEARBURN	19.0	0.54	0.02	6.7	80	4.3
	17.9	0.40	-	6.4		
	293.7	2.86	0.50	8.6		
COLDINGHAM	151.5	1.17	0.10	7.7	323	17.9
	87.9	0.17	0.01	7.1		
	137.5	1.19	0.05	7.3		
CROOKED	73.9	1.09	0.01	6.8	104	27.0
	32.3	0.13	0.01	6.0		
	19.2	1.10	-	6.5		
GAMESHOPE	13.6	1.00	0.01	6.2	42	2.8
	8.0	0.90	-	5.9		
	18.8	0.30	0.20	7.0		
HELLMOOR	18.3	0.15	0.10	6.9	85	8.5
	17.8	0.01	0.01	6.8		
	688.2	27.21	0.26	9.2		
HIRSEL	605.3	17.96	0.25	8.1	355	95.5
	550.1	8.80	0.24	6.9		
	5897.7	5.25	4.40	10.0		
HOSELAW	2084.1	2.62	1.30	7.9	193	70.4
	1077.6	0.27	0.01	6.5		

Table 2. (continued)

	13058.9	3.97	1.06	6.5		
HULE MOSS	6178.7	2.24	0.66	6.0	76	1044.2
	2103.8	0.10	0.35	5.8		
	46.1	2.43	0.49	8.4		
KINGSIDE	35.5	1.02	0.08	7.1	90	5.7
	24.7	0.17	0.01	5.2		
	20.6	6.05	0.96	8.0		
LINDEAN	17.6	1.40	0.04	7.4	200	5.1
	13.9	0.24	0.01	6.2		
	60.7	0.08	3.55	-		
MIRE	50.6	0.03	1.51	6.6	-	24.5
	41.4	0.01	0.07	-		
	197.0	1.80	0.01	7.7		
WHITTON	165.9	0.87	0.01	7.3	115	21.1
	138.6	0.40	0.01	6.8		
	67.5	4.02	1.90	8.4		
WILLIESTRUTHER	34.1	1.39	0.72	8.1	224	4.7
	18.2	0.10	0.01	7.4		
	435.1	1.00	0.01	4.4		
WINDYLAW	345.5	0.72	0.01	4.1	45	16.2
	294.6	0.54	0.01	3.8		
	1141.1	10.18	3.90	8.2		
WOODEN	669.5	6.63	1.48	7.9	317	35.6
	31.0	1.40	0.12	7.4		
	472.6	8.76	9.10	9.0		
YETHOLM	174.6	3.45	1.95	8.1	240	24.3
	93.7	0.41	0.01	7.2		

Number of observations for Phosphorus, Silica, Nitrogen and Chlorophyll *a* ranged from two (Gameshope) to thirteen (five sites); mean number = 6.4.

Number of observations for pH ranged from one (Mire) to nine (Hoselaw); mean number = 4.5.

Conductivity+ measurements were taken on a maximum of four occasions, with the exception of Coldingham loch (six).

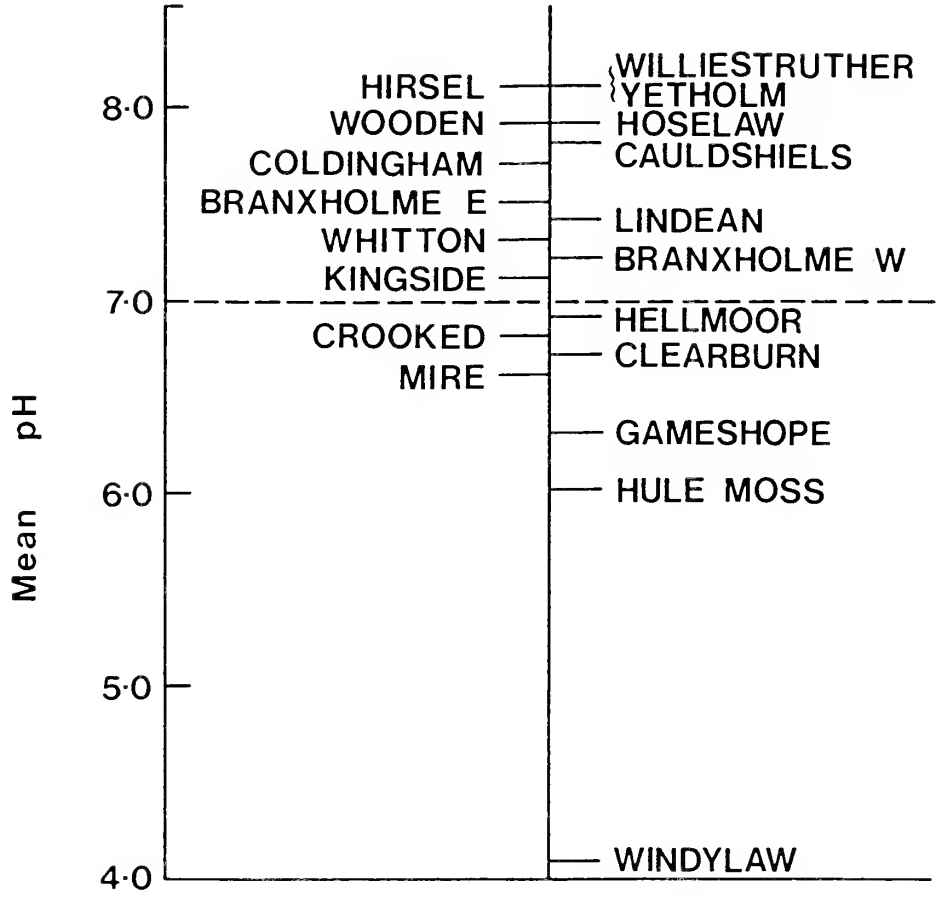


Figure 4

The ranked levels of
mean pH
for the nineteen Border lochs

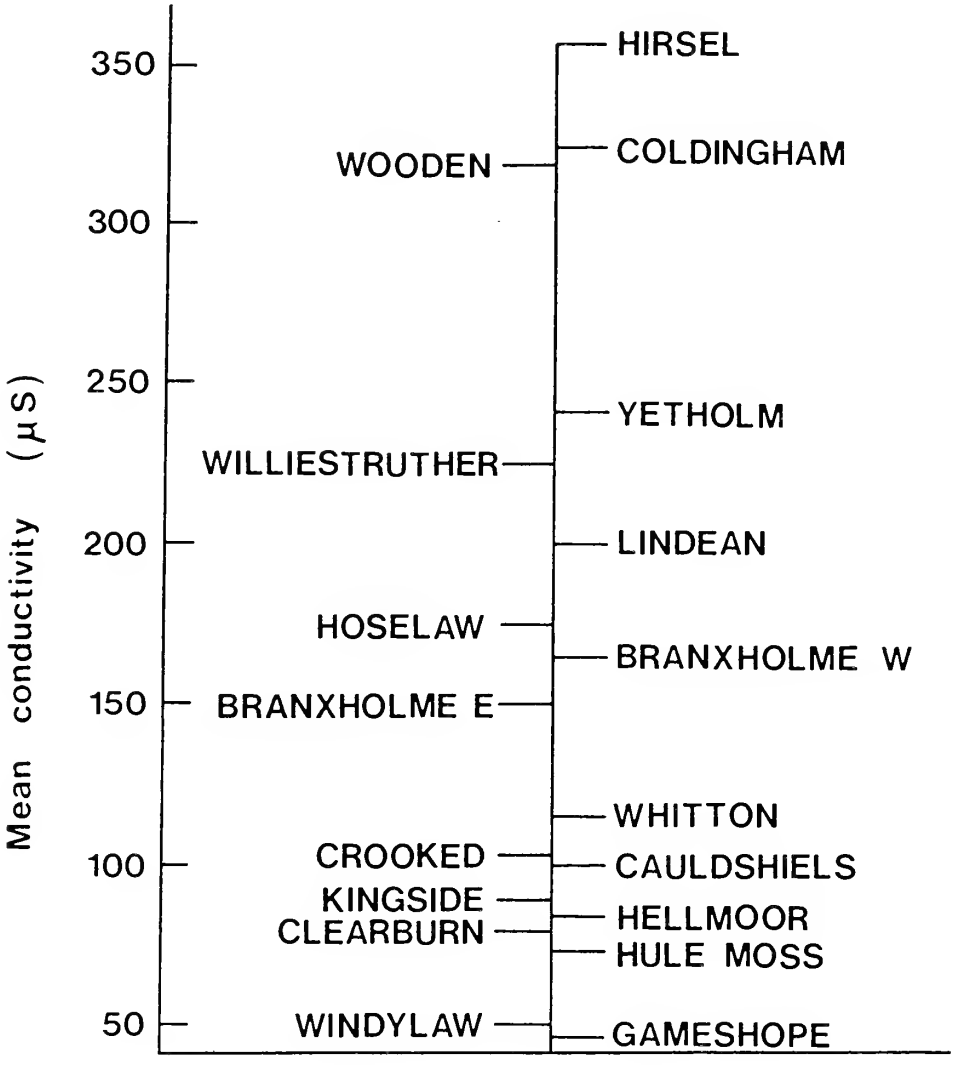


Figure 5

The ranked levels of
mean Conductivity ($\mu S/cm^{-1}$ @ 25°C)
for the nineteen Border lochs

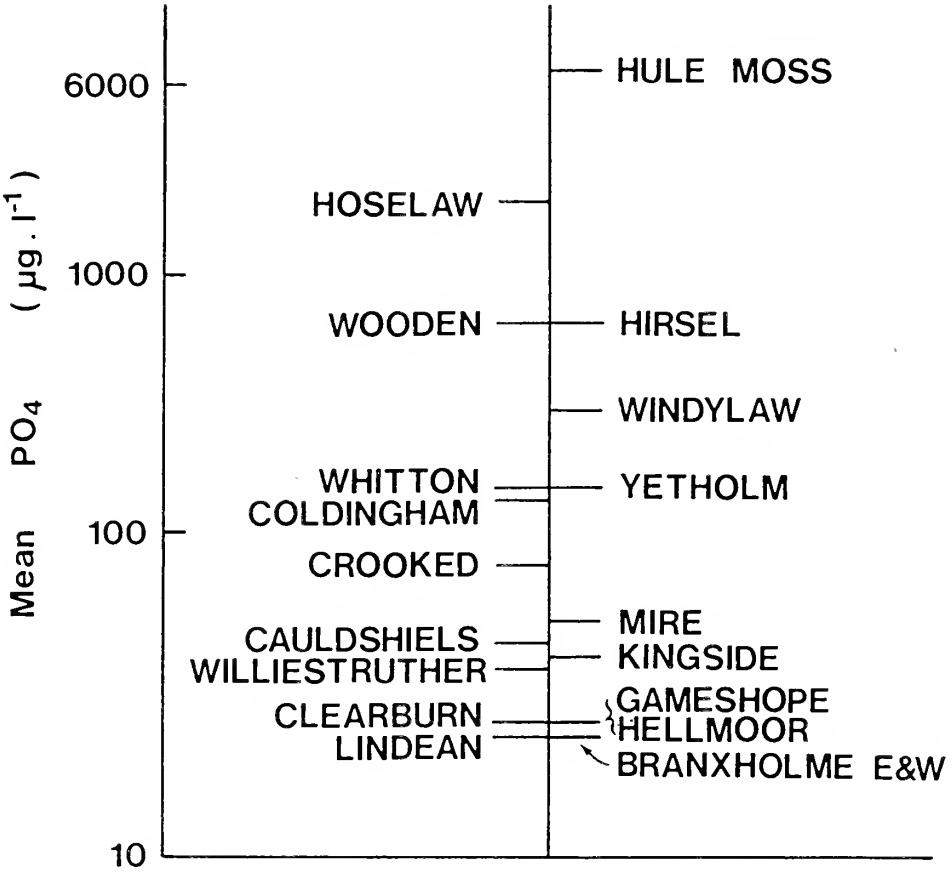


Figure 6

The ranked levels of
mean total Phosphorus ($\mu g/1^{-1}$ PO_4)
for the nineteen Border lochs
The values of Phosphorus are given in a log $10^{(x+1)}$ scale.

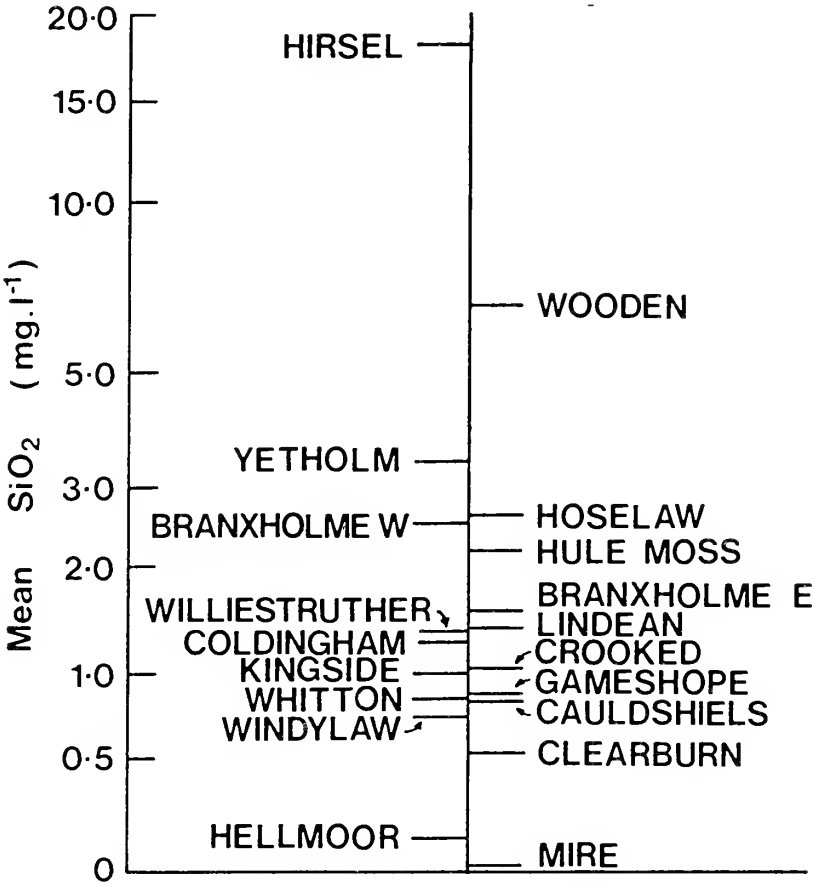


Figure 7

The ranked levels of
mean soluble Silica ($mg/1^{-1}$ SiO_2)
for the nineteen Border lochs
The values of Silica are given on a log $10^{(x+1)}$ scale.

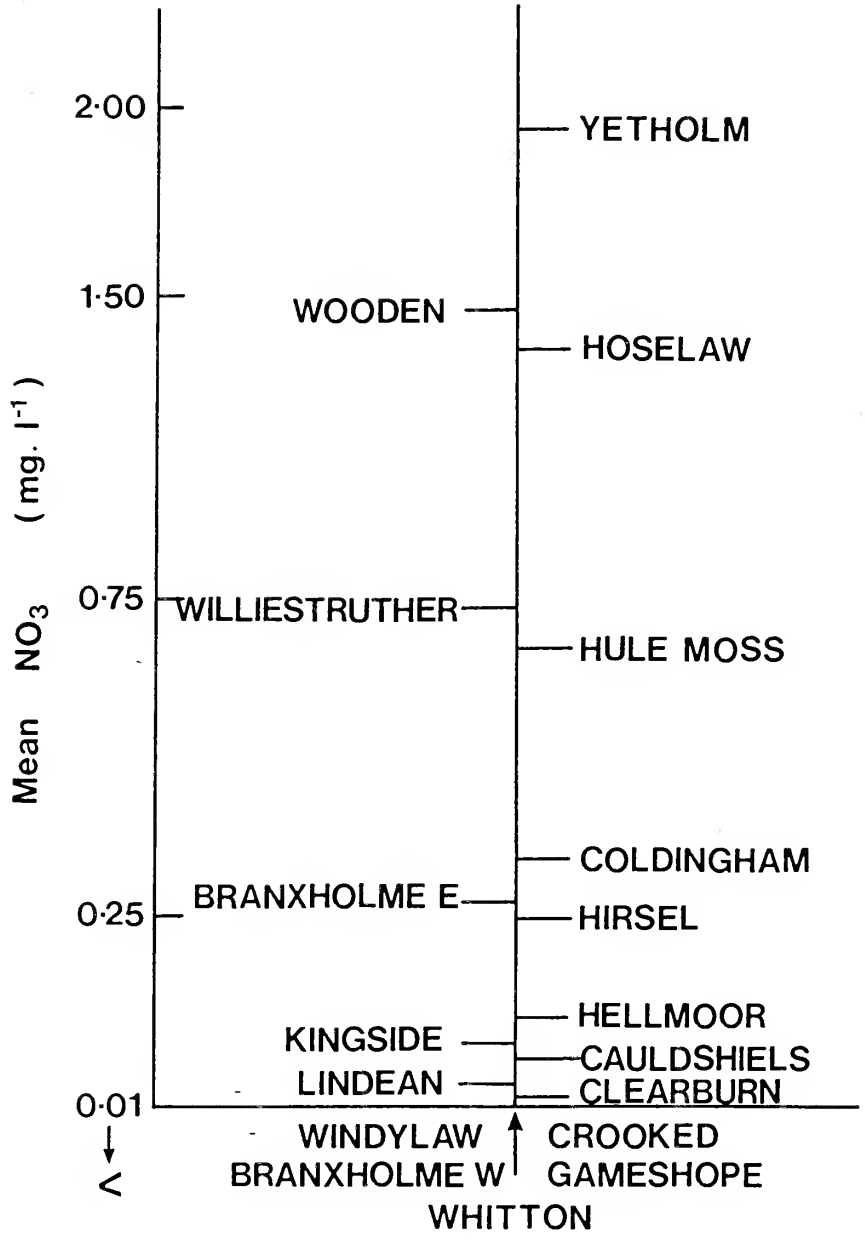


Figure 8

The ranked levels of
mean Nitrogen (mg/l^{-1} NO_3/N)
for the nineteen Border lochs

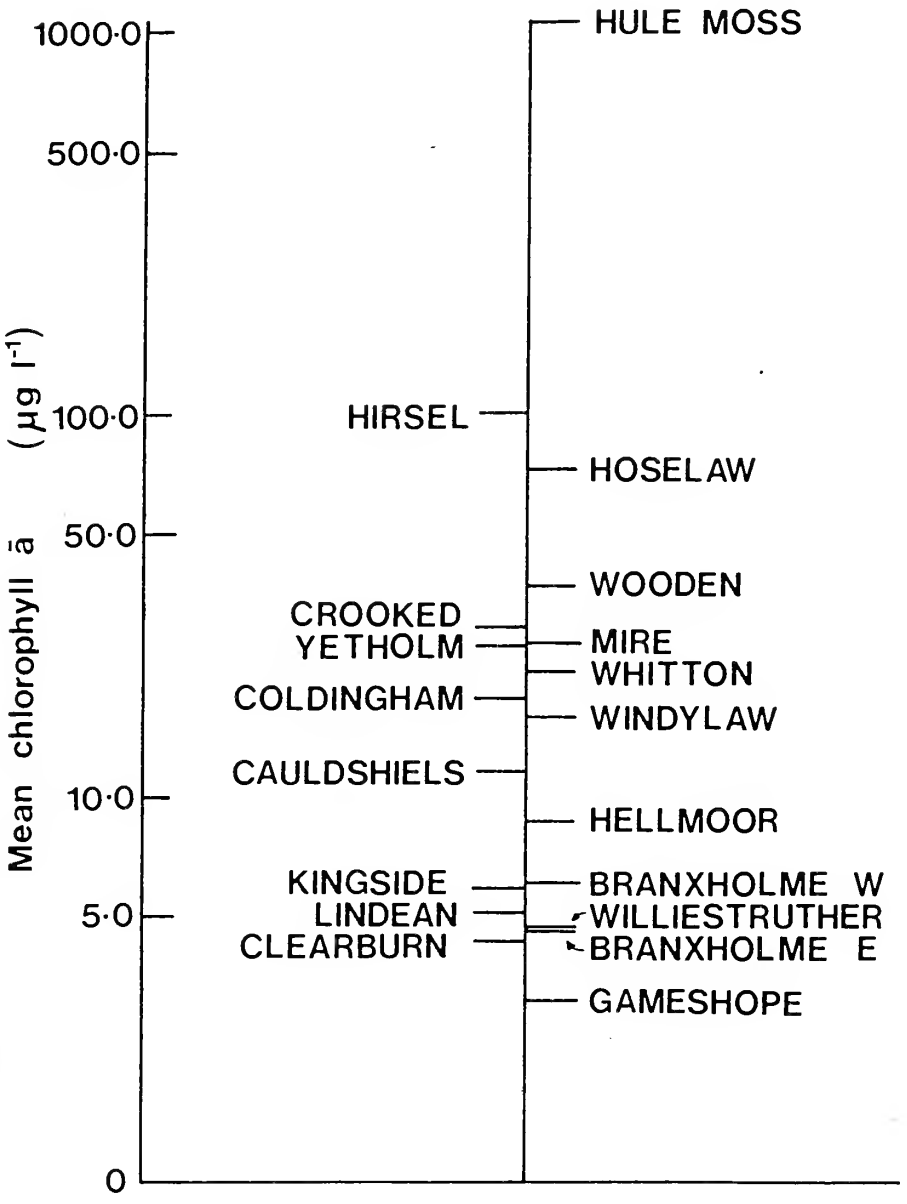


Figure 9

The ranked levels of
mean Chlorophyll *a* ($\mu g/1^{-1}$)
for the nineteen Border lochs
The values of Chlorophyll *a* are given in a log $10^{(x+1)}$ scale.

HIGH ALTITUDE SITES

This group includes Gameshope loch which, by comparison with the other five lochs, is outstanding because of its situation at an altitude of 560 m.a.s.l. in a catchment area where the land use is entirely rough grazing. The other sites all lie between 300 m and 360 m, and four of the catchments include afforested land, mainly coniferous plantations. Only above Clearburn loch does the land use resemble that of Gameshope and consist entirely of rough grazing. Kingside and Hellmoor lochs have catchments in which some 50% of the land is afforested, while the catchments of Crooked and Windylaw lochs are entirely afforested with conifers.

It is evident, particularly from the biological results, that these six sites do not resemble each other closely, and that conditions other than altitude, sub-surface geology and the principal land use, may play an important part in influencing the composition, relative abundance and taxonomic diversity of the species assemblages.

Gameshope

As expected, Gameshope loch is not chemically rich, and has the lowest conductivity and nitrate values of all nineteen sites, as well as having almost the lowest values for phosphate and silica; the mean pH of 6.2 is not particularly low for a lochan in such a situation, and there is quite a large stand of macrophytes. However, in line with its chemical poverty, the mean algal biomass (chlorophyll *a* 2.75 $\mu g/l^{-1}$) is the lowest of all the sites. By contrast, out of a possible 28 species of microcrustacea recorded in the survey, this loch had the highest number (12) of any site, mainly because there were eight species of epibenthic crustacea. *Diaptomus gracilis* did not occur, although it might have been expected to dominate the zooplankton in such a situation. Its absence was probably due to the shallowness of the loch, which may have prevented the normal life-cycle being enacted. As a consequence, and unexpectedly for a loch in such a situation, *Cyclops s. abyssorum* was the dominant species.

Clearburn

Clearburn loch was also chemically poor and, although more alkaline, was similarly low in algal abundance (chlorophyll *a* 4.3 $\mu g/l^{-1}$). Macrophytes were numerous, and although the microcrustacea consisted of only eight species, *Diaptomus gracilis* was dominant (58.9%) over *C. s. abyssorum* and *Daphnia hyalina*. *Diaphanosoma brachyurum*, *Alonopsis elongata* and *Alonella excisa* were also present, indicating that this is a

fairly typical hill loch with oligotrophic to mesotrophic conditions.

Hellmoor

Hellmoor loch, the largest water-body in the survey, showed similarly low chemical values except for nitrate, which was a little higher than for the other five sites. The chlorophyll *a* value was slightly above the minimal values of Gameshope and Clearburn lochs and the species assemblage was similar to the latter, with *Diaptomus gracilis* dominant. The absence of *Diaphanosoma* and the presence of *Acroperus harpae* suggest that, despite the presence of *Alonopsis elongata* and *Alonella excisa*, the conditions are slightly less rigorous than in Clearburn loch.

Kingside

Kingside loch differs from Hellmoor by being chemically slightly richer (higher values for phosphate and silica), although the land use in the catchments is very similar. The dominant species in the assemblage of Kingside were *Cyclops s. abyssorum* and *Daphnia hyalina*. *Diaptomus gracilis* was only found, at a very low level of abundance, on one occasion out of six visits. Macrophytes, especially submerged forms, appear to be extensive in the loch and the maximum depth may be no more than two to three metres, so that, like Gameshope, the loch may be too shallow to support a viable population of *Diaptomus gracilis*.

Crooked

The remaining two sites in this group, Crooked and Windylaw lochs, are about two kilometres from Kingside loch, but are entirely surrounded by coniferous forests. They are distinct in this way, and are biologically, and to some extent chemically, different from Kingside and Hellmoor and from each other. Although Crooked loch has a very low nitrate value, it is verging on a mesotrophic condition according to an assessment of all other chemical parameters measured, and algal abundance is high (chlorophyll *a* 27$\mu g/1^{-1}$). The species assemblage of microcrustacea was high in number (12) and included the mesotrophic cladoceran *Sida crystallina* as well as *Alona affinis* and *Ceriodaphnia quadrangula*. *Cyclops s. abyssorum* and *Diaptomus* were co-dominant, with *Daphnia hyalina* and *Bosmina longirostris* completing the planktonic species list.

Windylaw

Windylaw, on the other hand, proved to be the most unexpected and anomalous site in this group, with a mean pH of

4.1 based on five measurements. The brown water, the absence of a positive inflow, and only a slight outflow, made it appear to be a typical dystrophic moorland pool. However, the mean value for chlorophyll *a* (16.2 $\mu g/l^{-1}$) is unexpectedly high for such a site and places it at the half-way point in ranking of the 19 sites (Figure 9). The cause of this unexpected occurrence must be the high phosphate value, (fifth ranked at 345.5 $\mu g/l^{-1}$ PO_4). Even without considering the acidic nature of the water (pH 4.1), it is likely that low levels of the other chemical parameters limit productivity, since values for nitrogen, silica and minerals (mean conductivity of 45 $\mu S/cm^{-1}$) were all extremely low.

The expected dominance of *Diaptomus gracilis* (83.3%) occurred in Windylaw loch, and *Daphnia hyalina* was absent, despite the abundance of algae, since it prefers a higher pH. *Diaphanosoma brachyurum* seems to prefer moderately acidic and possibly dystrophic conditions and was present, although, somewhat surprisingly, *Scapholeberis mucronata*, which in general seems to prefer mesotrophic conditions (Jones, 1989), was a numerically important constituent of the plankton. *Alonella excisa* and *Bosmina coregoni*, typical of oligotrophic, dystrophic, low pH waters, both occurred, although at low levels.

MEDIUM ALTITUDE SITES

This second group consists of seven sites which range in altitude from 270 to 205 m.a.s.l., although only 30 metres separate the top six sites. None of them is in a fully afforested catchment although some catchments include coniferous plantations, and others include natural, mainly deciduous, woodland. Much of the land is used for agriculture, including some enclosed, improved grazings, although other catchments are open, rough moorland. In general, the range covered is that of marginal land, so that where upgrading is taking place, fertilisers may well be in regular use.

Branxholme Easter

Branxholme Easter and Branxholme Wester, despite their proximity to each other and their identical altitude, differ in many respects. The former resembles a small corrie loch, but is surrounded by well-grazed grassland. The inflow runs through a small coniferous plantation and a small amount of drainage may also occur from a coniferous plantation on the east side. The ten species recorded in the epibenthic and zooplankton samples include the usual three dominant species, with *Diaptomus* forming 60.7% of the zooplankton population. The pH is relatively high

(c. 7.5), as is conductivity (150 $\mu S/cm^{-1}$), but phosphorus, nitrate and silica are all fairly low, so not surprisingly the mean chlorophyll *a* value is low (4.56 $\mu g/1^{-1}$). However, the generally alkaline, relatively mineral-rich conditions allow such species as *Eurycercus lamellatus*, *Alona affinis* and *Pleuroxus trigonellus* to thrive.

Branxholme Wester

Branxholme Wester, a smaller, shallower loch, is sheltered within an area of woodland, and although not distinctly different by chemical parameters, differs biologically in having *Cyclops s. abyssorum* dominant and also has *Ceriodaphnia quadrangula*, *Sida crystallina* and *Cyclops leuckarti* in the species assemblage. Like Crooked loch, which it resembles superficially in appearance, a considerable area of the shallow waters of the loch is occupied by macrophytes.

Whitton

Whitton loch and Hule Moss are two sites which can be considered together, since they are both in an open moorland situation, remote from human activity. The former is a small shallow loch on an open hill top surrounded by rough grazing land which is stocked frequently with sheep and cattle. The land adjacent to this area is being ploughed and reseeded. There is no woodland in the small catchment area. The pH values ranged from 6.8 to 7.7 and conductivity was moderate at 115 $\mu S/cm^{-1}$. However, the mean level of chlorophyll *a* was relatively high at 21.10 $\mu g/1^{-1}$, due no doubt to a fairly high mean value for phosphorus. This not only accounted for the dominance of *Cyclops s. abyssorum*, but also for the thriving population of *Daphnia magna*. The number of species in the assemblage was restricted to five, and generally these two factors are indicative of eutrophic condition.

Hule

Hule Moss, despite being situated in a shallow depression in open moorland, is an exceptional loch with abnormally high levels of phosphorus (6188.7 $\mu g/PO_4/1^{-1}$) and chlorophyll *a* (1044.2 $\mu g/1^{-1}$), and also has high values for silica and nitrate. The microcrustacean fauna is extremely low in diversity, but is very abundant. It consisted only of *Cyclops s. abyssorum* and *Daphnia obtusa* as the planktonic component, and *Chydorus sphaericus* - a very tolerant cladoceran - as the only representative of the epibenthos.

Cauldshiels

Of the remaining medium altitude sites, Cauldshiels is

perhaps the most typical. The mean pH is 7.8, although the highest single value was 9.0. Despite this, water chemistry indicates that the loch is not rich (phosphorus 39.8 $\mu g/PO_4/1^{-1}$), conductivity only reaching 101 $\mu S/cm^{-1}$, and consequently the mean level of chlorophyll *a* is not especially high. However, the biological parameters are mainly typical of mesotrophic waters, with *Cyclops s. abyssorum* being dominant (43.4%) over *Diaptomus gracilis*, and *Daphnia hyalina* along with *Alona affinis*, *Ceriodaphnia quadrangula*, *Cyclops leuckarti* and *Pleuroxus trigonellus* being present in the fauna. Surprisingly and problematically, *Diaphanosoma brachyurum* was found once in this loch, and in one season a 'bloom' of blue-green algae was noted on the substrate of the littoral zone.

Lindean and Williestruther

Lindean and Williestruther lochs are both believed to be in 'marling' condition. Each has strong stands of macrophytes, clear water and only a low level of abundance of microcrustacea. The mean level of chlorophyll *a* was low, only about 5.0 $\mu g/1^{-1}$ at both sites, as were phosphorus levels. Silica levels were a little higher, but the main difference was in the nitrate level, which was high in Williestruther (0.72 $mg/1^{-1}$) but low in Lindean (0.04 $mg/1^{-1}$). Conductivity, however, was high in both waters (200 and 224 $\mu S/cm^{-1}$). The zooplankton was dominated by *Diaptomus gracilis*, since it formed 80.0% of the plankton population in Williestruther and 54.4% in Lindean, although, apart from this, the species assemblages are fairly typical of mesotrophic waters, especially the presence of *Simocephalus vetulus* in Williestruther loch, typical of the alkaline conditions, especially the high (8.1) pH.

LOW ALTITUDE SITES

The altitudes of the remaining sites range from 25 metres to 180 metres and the catchment areas are not large (<66 ha) with the exception of Yetholm loch (428 ha). Here, because of the area involved, the catchment extends up into marginal land.

Hoselaw and Coldingham

Hoselaw and Coldingham lochs are similar in size; they are both surrounded by improved grazing and arable land and have catchment areas almost identical in size. Each is biologically very productive and suffers from algal blooms. Mean chlorophyll *a* measurements are, respectively, 70.36 and 17.9 $\mu g/1^{-1}$, suggesting that Hoselaw loch is hypereutrophic, whereas Coldingham loch by this standard should more probably be classed as mesotrophic. Phosphorus levels parallel these values for phytoplankton abundance, since Hoselaw has a mean value of over

2000 $\mu g/1^{-1}$ and a maximum value approaching 6000 $\mu g/1^{-1}$, as well as high values for nitrate and silica. Coldingham loch in contrast has mean and maximum phosphorus values of 150 and nearly 300 $mg/1^{-1}$, as well as much lower values for nitrate and silica. Assessment on the basis of the microcrustacea agrees with these interpretations, since although both sites have the three basic species, *Cyclops s. abyssorum* was dominant in Hoselaw and there were also high numbers of *Daphnia magna* and *D. atkinsoni*. The presence of *Ilyocryptus sordidus* brought up the total number of species in this loch to six, indicative of an enriched loch. Coldingham on the other hand produced twelve species, with six planktonic forms, five of which were numerically abundant at some time of the year, but overall, *Diaptomus gracilis* was slightly more abundant (34.2%) than *Cyclops s. abyssorum* (27.5%). *Bosmina longirostris*, *Ceriodaphnia quadrangula* and *Daphnia hyalina* were also abundant at particular periods of the year.

Yetholm and Wooden

Yetholm and Wooden lochs resemble each other, in that they are both adjacent to well-stocked cattle grazing land and close to farm buildings from which seepage, if not drainage, may take place. The principal difference between them is in the catchment areas. The former, as noted above, is extensive and lies on the foothills of the Cheviot Hills. Biologically the sites differ; Wooden loch had only four microcrustacean species, of which *Daphnia magna* was one, and the three basic species formed the remainder. Sampling for epibenthic crustacea was totally unsuccessful, the only places available for sampling being at points where the cattle trampled the littoral area. Yetholm loch, on the other hand, while having *Daphnia magna* present on one occasion also had *Alona affinis*, *Pleuroxus trigonellus* and *Ceriodaphnia quadrangula* among the species present. *Bosmina longirostris* was common in conjunction with *Cyclops*, *Diaptomus* and *Daphnia hyalina*. This assemblage of ten species indicates a condition similar to Coldingham, with the conditions being mesotrophic, verging on eutrophic.

Mire

The two remaining sites, Mire loch and the Hirsel lake, are quite distinct and differ considerably from each other. The former lies close to the coastline behind St. Abbs Head and may well suffer from some deposition of sea-spray, although the recorded pH value of 6.6 does not suggest that there is a strong marine influence. Unfortunately, conductivity values are not available for this site. Phosphate is low here in comparison with the other low altitude lochs, but nitrogen is very high.

The combination, however, gives a value for chlorophyll *a* of 24.47 $\mu g/1^{-1}$, which is in the top third for these nineteen lochs. The value for silica was quite low (0.03 $mg/1^{-1}$). The importance of this to the dominance of *Diaptomus gracilis* is uncertain, but neither *Cyclops s. abyssorum* nor *Daphnia hyalina* were abundant in any samples from the Mire loch. Epibenthic microcrustacea were absent except for the ubiquitous *Chydorus sphaericus*, which leaves this site as a somewhat enigmatic problem.

Hirsel

The Hirsel lake, an artificial water-body constructed for aesthetic and sporting purposes, is another anomaly. It is nowhere deeper than a few metres, has little indication of positive inflow or outflow, and has not only a wide border of emergent macrophytes, but also a cover of submerged macrophytes over much of the bed of the loch. More than half the perimeter is overgrown by trees. Chemically, it is outstanding by reason of its incredibly high values for silica (mean value 17.96 $mg/1^{-1}$, maximum 27.21 $mg/1^{-1}$). Coupled with this are high values for phosphorus and a mean chlorophyll *a* value of 95.50 $\mu g/1^{-1}$. Not surprisingly, the microcrustacean fauna is extremely abundant, but very restricted in species. *Cyclops s. abyssorum* and *Daphnia magna* dominate the samples, while *Daphnia hyalina* is occasionally abundant when numbers of *D. magna* are reduced. *Ceriodaphnia quadrangula* also occurs occasionally in small numbers. No epibenthic Crustacea were found, and it appears that this is a typically eutrophic/hypereutrophic lake.

Discussion

Of the nineteen lochs examined in this survey, only a few can be considered entirely 'natural'. Prediction of their expected trophic status on the basis of physical and geological map data could only be confirmed in a few instances by the field survey data. 'Unnaturalness' in a number of waters, as indicated by high chlorophyll levels, abundant Crustacea, but very few species, appears to have resulted from abnormal water chemistry, due to a variety of activities, some of which have been introduced by man.

Natural Evolution and Human Influence

Some operations which are believed to be at least potentially responsible include the improvement of upland grazing by ploughing, fertilizing and reseeding, followed by increased stocking, the extension of afforestation with the consequent applications of fertiliser, and, of course, at lower

altitudes the regular applications of fertiliser to encourage rapid and early growth of grass, cereals and other field crops. High production feeding of cattle must also play a part in the chemical enrichment of waters draining pastureland, and coupled with these problems are two others, neither of which is easily controlled.

The first is that a number of these water bodies are at a late stage in their natural evolution. Their small catchment area, surface area and relatively shallow depth ensures that both autochthonous and allochthonous materials are held and deposited in the loch instead of being carried through to the outflow. The ensuing extension of marginal vegetation towards the centre of the loch may lead to the occlusion of open water.

The second problem is that chemical enrichment of waters results from the roosting of large flocks of birds, especially wild geese in the winter.

An attempt has been made to fit the nineteen sites into the above scenario, in the belief that they form a reasonable sample of the area's resource, and comment is made on the likely future of such lochs in the Borders Region.

Clearburn, Hellmoor, Branxholme Easter and Cauldshiels are considered, with a few minor reservations, to be more or less 'natural' representatives of upland and marginal lochs, while Coldingham and Yetholm are representative of fairly rich lowland areas. Lindean and Williestruther are distinctly different from most of the others, but do not appear to be currently affected by any man-made conditions.

Of the remaining eleven sites, it appears that Gameshope, and probably Kingside, Crooked and Windylaw are approaching senescence, while the latter also appears to be chemically affected since it had an unusually high level of phosphorus. It is possible that the phosphorus could result from roosting wildfowl, but it seems more likely that, since phosphates are applied to the land during the early years of tree-growth, there may have been an accumulation of phosphates in the loch due to drainage and seepage. Because of the small and intermittent outflow, the leached phosphate has probably collected in the sediment and total biomass during the years in which the forest has grown. The last known application of phosphatic fertiliser made to this area of Craik forest was in 1982 (C.O. Badenoch, pers. comm.).

High Phosphorus Levels: Cause and Effect

Excessive amounts of phosphates in the waters of other sites have been mentioned, and at some they have been coupled

SITES Grouped by Altitude and Land-use	SPECIES														
	Cyclops strenuus abyssorum (Sars)	*Eudiaptomus gracilis* (Sars)	*Daphnia hyalina* var. *lacustris* Sars	*Chydorus sphaericus* (O.F. Müller)	*Bosmina longirostris* (O.F. Müller)	*Alona affinis* Leydig	*Alonella nana* (Baird)	*Ceriodaphnia quadrangula* (O.F. Müller)	*Daphnia magna* Straus	*Eurycercus lamellatus* (O.F. Müller)	*Acroperus harpae* (Baird)	*Pleuroxus trigonellus* (O.F. Müller)	*Diaphanosoma brachyrum* Liéven	*Alonopsis elongata* Sars	*Alonella excisa* (Fischer)
High															
GAMESHOPE	35.0	-	+	+	-	-	+	-	-	+	+	-	+	+	+
CLEARBURN	+	58.9	+	+	-	-	+	-	-	-	+	-	+	+	+
HELLMOOR	+	53.8	+	+	-	-	+	-	-	+	+	-	-	+	+
KINGSIDE	68.0	+	+	+	-	+	+	+	-	+	+	+	-	-	-
CROOKED	25.2	25.2	+	+	+	+	+	+	-	+	+	-	-	-	+
WINDYLAW	+	83.3	-	+	-	-	-	-	-	-	-	-	+	-	+
Medium															
BRANXHOLME E	+	60.7	+	+	+	+	+	-	-	+	-	+	-	-	-
BRANXHOLME W	55.2	+	+	-	+	+	+	+	-	-	-	-	-	-	-
WHITTON	52.1	+	+	+	-	-	-	-	-	-	-	-	-	-	-
HULE MOSS	85.4	-	-	+	-	-	-	-	-	-	-	-	-	-	-
CAULDSHIELS	43.4	+	+	-	-	+	-	+	-	-	+	+	+	-	-
LINDEAN	+	54.4	+	+	+	+	+	-	-	+	-	-	-	-	-
WILLIESTRUTHER	+	85.0	+	+	-	-	-	+	-	-	-	-	-	-	-
Low															
HOSELAW	55.1	+	+	-	-	-	-	-	+	-	-	-	-	-	-
COLDINGHAM	+	34.2	+	+	+	+	-	+	-	+	+	-	-	-	-
YETHOLM	+	34.2	+	+	+	+	-	+	+	-	-	+	-	-	-
WOODEN	44.9	+	+	-	-	-	-	-	-	-	-	-	-	-	-
MIRE	+	53.8	+	-	-	-	-	-	+	-	-	-	-	-	-
HIRSEL	73.0	-	+	-	-	-	-	+	+	-	-	-	-	-	-
SITES PER SPECIES	19	16	17	14	6	8	6	8	5	6	6	4	4	3	5

Table 3

Presence (+), absence (-) and, for two species, percentage relative abundance, of 28 planktonic or epibenthic Crustacea in nineteen Border lochs.

SITES Grouped by Altitude and Land-use	SPECIES																
	Alona spp. (non-*affinis*)	*Mesocyclops leuckarti* (Claus)	*Eosmina coregoni* v. *obtusirostris* Sars	*Sida crystallina* (O.F. Müller)	*Ilyocryptus sordidus* (Liéven)	*Peracantha truncata* (O.F. Müller)	*Simocephalus vetulus* (O.F. Müller)	*Daphnia atkinsoni* Baird	*Daphnia obtusa* Kurz	*Cyclops vicinus* Ulanine	*Scapholeberis mucronata* (O.F. Müller)	*Drepanothrix dentata* (Eurén)	*Leydigia leydigi* (Schödler)	Planktonic species	Benthic species	Total species
High																
GAMESHOPE	-	-	+	-	-	+	-	-	-	-	-	+	-	4	8	12
CLEARBURN	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	8
HELLMOOR	-	-	-	-	-	+	-	-	-	-	-	+	-	3	8	11
KINGSIDE	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	8
CROOKED	-	-	-	+	-	-	-	-	-	-	-	-	-	6	6	12
WINDYLAW	-	-	+	-	-	-	-	-	-	-	+	-	-	5	2	7
Medium																
BRANXHOLME E	+	-	-	-	-	-	-	-	-	-	-	-	-	4	6	10
BRANXHOLME W	-	+	-	+	-	-	-	-	-	-	-	-	-	7	2	9
WHITTON	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	5
HULE MOSS	-	-	-	-	-	-	-	-	+	-	-	-	-	2	1	3
CAULDSHIELS	-	+	-	-	-	-	-	-	-	-	-	-	-	6	3	9
LINDEAN	+	-	-	-	-	-	-	-	-	-	-	-	-	4	5	9
WILLIESTRUTHER	-	-	-	-	-	-	+	-	-	-	-	-	-	5	1	6
Low																
HOSELAW	-	-	-	-	+	-	-	+	-	-	-	-	-	5	1	6
COLDINGHAM	-	-	-	-	-	+	-	-	-	+	-	-	+	6	6	12
YETHOLM	-	-	-	-	+	-	-	-	-	-	-	-	-	6	4	10
WOODEN	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0	4
MIRE	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	4
HIRSEL	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0	4
SITES PER SPECIES	2	2	2	2	2	3	1	1	1	1	1	2	2			

Table 3 (continued)

Presence (+), absence (-) and, for two species, percentage relative abundance, of 28 planktonic or epibenthic Crustacea in nineteen Border lochs.

with a high level of nitrate. The most outstanding of these is Hule Moss, a small, quite shallow loch in open moorland which, as previously mentioned, had a very high value for phosphate and a fairly high value for nitrate. Hoselaw, with 2084 $\mu g/l^{-1}$ of phosphate and 1.30 mg/l^{-1} of nitrate was also outstanding. Both sites are noted for their flocks of roosting wild geese. The moorland surrounding Hule Moss is ideally situated for this purpose, being remote and virtually free from human disturbance. Observations reported during the last ten years have indicated that the winter visiting population of wildfowl has increased from 1,000 birds in 1975 to 7,500 birds in 1979, while in early May 1985, over 10,000 birds were estimated to have flown in and settled on or beside the loch. Even a small percentage of this number roosting regularly in the area will lead to a build-up of chemicals, especially phosphates and nitrates, in the loch and surrounding soil (Hancock, 1982; Bazely and Jeffries, 1985; Bedard and Gauthier, 1986).

Whitton loch is also a roosting site for geese, in an open moorland situation at 255 m.a.s.l. where high levels of phosphorus would not otherwise be expected. Nitrogen, which is more likely to be found as a run-off material from agricultural sources is, however, minimal in this loch despite there being improved grazing in the catchment. Hoselaw is in a relatively low-lying (180 m.a.s.l.), geologically base-rich area which is liable to receive agricultural run-off, and since geese commonly graze and roost beside the loch, both sources may account for its chemical richness. Wooden loch has similarly high values for these materials, also for silica, and these four lochs, together with Hirsel lake (very high silica and high phosphorus), have all had, at least for part of the survey period, significant populations of the less common species of *Daphnia* (*D. magna*, *D. atkinsoni* and *D. obtusa*) whose presence seems to be linked very closely to the occurrence of roosting migratory birds and the resultant chemical richness, especially phosphates and nitrates (Jones, 1984b).

Fluctuating *Daphnia* populations

As long as such sites are regularly used, the chemical enrichment will continue, biological productivity will be maintained or increased, and introductions and 'topping-up' of such populations of uncommon species will occur. As birds move from one site of this type to another similar site they will probably carry either live specimens, or mud containing the eggs or resting stages. However, it appears that not all such sites have maintained their *Daphnia* populations in this way.

In 1983 and 1984 Hoselaw and Yetholm lochs each supported a

population of *Daphnia magna*, and in the former it was accompanied by a population of *D. atkinsoni*. One specimen of *D. atkinsoni* was found in Yetholm loch, but a full population was never confirmed. In 1985 and 1986 neither species was taken in either loch. Wooden loch, Whitton loch and Hirsel lake were first sampled in 1984 and populations of *D. magna* were found at these sites too, but the population in Wooden loch failed to reappear in the spring of 1985 and 1986. The populations in Whitton loch and Hirsel lake persisted; in the former until at least 1986, and in the latter until the present day (1988). The reasons for these differences in behaviour are uncertain, but it seems probable that populations need to be augmented fairly frequently by migrant birds. Ice cover in the cold winters of 1984-85 and 1985-86 seems to be an unlikely cause of the species failure, because Whitton loch is some 180 m higher than Hoselaw and more exposed to frost and cold winds. The behaviour of the population of *D. magna* in Wooden loch is easier to understand. Reintroduction by geese is less probable here because of the proximity of farm buildings, and since this loch is restocked annually with trout, these fish will actively seek the larger Crustacea for food (Duncan, 1975).

Mire loch might be expected to shelter migrant geese in large numbers since the area is a common landfall for passerines blown off course during migration flights. However, apart from there being no evidence for large flocks of geese, there is a very low value for phosphates. The high value for nitrates is most probably due to run-off from arable and pasture land in the catchment. Silica, despite the presence of an extensive reed-bed at one of the lochs, appeared on average to be low. The relative proportions of these chemical parameters may possibly, through the algal population, account for the unexpected crustacean species assemblage in this loch.

Summary and Further Considerations

Despite the fact that this survey has taken place on an *ad hoc* basis, and sampling has not been carried out with the same intensity in each year or at all sites, it has provided a picture of the status of some typical water bodies of the Borders Region, and the findings obtained here may well have a much wider application. Because sampling has taken place over four years, a perspective has been given to the results which might not have been available had only one or two seasons been covered. The transient nature of the presence of *Daphnia magna* and *D. atkinsoni* at some sites was unexpected. Their presence in Scotland (Harper, 1976; Jones, 1984a) had tacitly been assumed to be a development which, once it had occurred, would be 'permanent' so long as the characteristics of the water-bodies

concerned did not undergo a major change. However, in the Border lochs this seems not to be the case. This fact has demonstrated the possibility that similar fluctuations may occur with other species and with the chemical parameters.

Of particular concern also is the strong possibility of an association between the natural senescence of some of these lochs and the chemical changes which are taking place. In many ways, because of their small size and shallow depth, the lochs are very much at risk to excessive increases in the production of organic matter, with results such as those outlined above.

Marginal and lowland sites with extensive shallows in areas where cattle and sheep graze are perhaps the places where both organic (faeces and urine) and inorganic (fertiliser) inputs may be especially important, since in a relatively short time they may well unbalance a delicately poised system.

The problem of huge flocks of roosting birds is more difficult to counteract, but sites such as Hule Moss, which is presently very unnatural, may well become totally unacceptable to crustacean zooplankton, either because of chemical effects (including decomposition products) or physical effects, such as the build up of organic debris. The water may become too shallow to support the normal life-cycles of the fauna.

A further consideration is the effect of continued acid deposition. Despite the reported decline in the rate of sulphur dioxide deposition since the end of the 1970s (U.K. Review Group on Acid Rain, 1987) and the possible reduction of industrial emissions through the present decade, it is worrying that, overall, there was no increase in the pH values of these waters during 1983-1986 (see Figure 10). Admittedly there are few results, and pH is a notoriously difficult parameter to measure accurately and repeatedly, but at each site where a sequence of values has been taken, there appears to be a downward trend, i.e. towards greater acidity. Such a 'trend' cannot be taken as scientific fact, but the statistical pattern should, by all the rules, have been random or, in view of reduced deposition of acidic materials, upwards; and it is not. The buffering role played by the solid geology of much of the area could be insufficient, in some of these sites, to overcome the slow transport of water through the system of small lochs with their high retention times. In addition, drift geology or intrusive non-basic rocks may provide a significant local counter-influence.

To summarise, the continued existence of a number of lochs in the Borders Region may well be at risk because of their small size, shallow depth, and changes of land use in their catchment

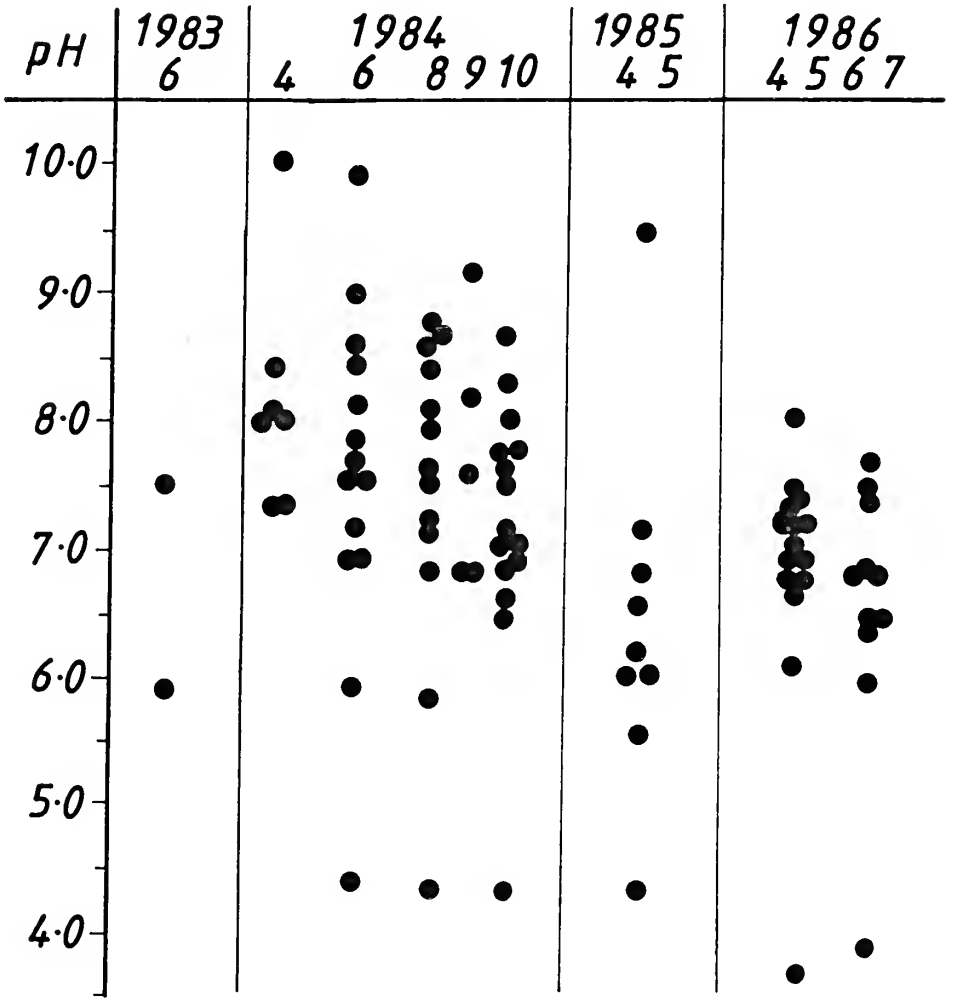


Figure 10

Single pH readings from eighteen sites taken in the months April to October between 1983 and 1986, demonstrating a possible change in the range of values over the years 1984-1986.

areas. This may well be representative of the situation in other parts of Britain. If it were possible to develop more extensive surveys of fresh waters in sensitive areas, it might show the numerical strengths and weaknesses of the existing diverse range of sites. A monitoring watch could then be maintained on those sites most sensitive to rapid change. If a close link were forged between the management of agricultural or forestry land and ecological studies of associated water bodies, further surveys might provide a better insight into the joint requirements of management for commerce and management for scientific and aesthetic considerations. These, and the monitoring watches, could provide essential, ongoing information about the land/water interface situation throughout the country, and so help to extend our ecological understanding of a number of problems. The results from this small and relatively simple study have perhaps provided a basis for extending the work in such a manner.

Acknowledgements

I should like to express my best thanks to my colleagues, Mr. Tony Bailey-Watts and Mr. Alec Kirika, and to Mr. C.O. Badenoch of the Nature Conservancy Council, for initiating and encouraging my interest in this study; also for the help they have given me in the field. Mr. Kirika carried out most of the chemical and chlorophyll *a* analyses. For their advice and their cooperation over access to the sites, I wish to thank the many landowners, their factors, other staff and tenants, all of whom have been very helpful. Numerous colleagues have made many helpful comments and criticisms during the preparation of this paper.

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Mr. David H. Jones, Institute of Terrestrial Ecology, Bush Estate, PENICUIK, Midlothian EH26 OQB.

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THE INFLUENCE OF ALEXANDER WILSON UPON JOHN JAMES AUDUBON

By CLARK HUNTER
Society for the History of Natural History

Preface

[In 1985 the Society for the History of Natural History and the Friends of Glasgow University Library held a joint meeting in Glasgow to commemorate the 200th anniversary of the birth of John James Audubon, and Mr. Clark Hunter, the distinguished authority on Alexander Wilson and author of the recently published monograph on *The Life and Letters of Alexander Wilson* (American Philosophical Society, 1983), was invited to give a talk on Alexander Wilson, the Scottish pioneer of American ornithology, and his influence on Audubon.

In the past, the circumstances surrounding the publication of these two authors' monumental early works on American ornithology had often been clouded by controversy and ill-informed comment, so the 200th anniversary of Audubon's birth seemed an excellent time to clear the air and establish the known and proven facts.

Following the interest aroused by Mr. Hunter's talk, it was felt that the simple but important conclusions of Mr. Hunter's paper, which threw fresh light on how Wilson and his pioneer work had clearly stimulated Audubon to his great endeavours, merited a much wider circulation than could be obtained even at the well-attended meeting, so the following is a slightly modified version of Mr. Hunter's address, delivered to the joint meeting of the two Societies held on 24th October 1985 in the Special Collections Department of Glasgow University Library, and published here with the ready cooperation of the Editors of the *Scottish Naturalist*.]

Introduction

When it was originally suggested to me, in the course of preliminary discussions with the joint committee, that I might give a talk on the 'relationship' between Wilson and Audubon, the first thought which occurred to me was that Alexander Wilson would probably have been astounded to learn that he had any kind of relationship with John James Audubon at all! The content of this paper has therefore been suitably corrected to 'The influence of Alexander Wilson upon John James Audubon'.

Any suggestion of 'relationship' reflects the bitter claims and charges of plagiarism which were flung about like brickbats more than a century ago and which are still not forgotten, so this is probably a very good time and place to state some plain facts which should clearly be much more widely known.

Dates

It is important to underline the dates when these two great ornithologists were working and publishing the results of their labours. Wilson was born in 1766, nineteen years before Audubon in 1785. Wilson died in 1813 at the age of 47, and Audubon in 1851 at the age of 66.

Wilson first announced in 1803 that he was about "to make a collection of our finest birds". The first volume of his *American Ornithology* was published in 1808, and after Wilson's death in 1813 the final 8th and 9th volumes were edited by George Ord, Wilson's friend and later the self-appointed guardian of Wilson's name and fame.

Audubon himself stated that he commenced work on *The Birds of America* in 1820, and the first selection of his plates was published in London in 1827, fourteen years after Wilson's death.

Wilson's Early Career

It may be helpful to recount briefly the beginning of Wilson's career as a serious ornithologist. He left Scotland in 1794 at the age of 28, when his combined activities as a poet and reformer had made his future in Scotland at a time of revolution - the French, American and Industrial Revolutions - insecure, and indeed dangerous.

Wilson, well educated for his time, was a man of many talents, which he exhibited in America by working first as a copper-plate printer, then as a weaver, later as a pedlar, and eventually as a schoolmaster at Milestown, Pennsylvania. Early in 1803 it was Wilson's great good fortune to become schoolmaster at Gray's Ferry, Philadelphia. His school adjoined Bartram's Garden, a botanical garden created by John Bartram (1699-1777) who, although untaught, was described by Linnaeus as "the greatest natural botanist in the world". There Wilson soon became acquainted with John Bartram's son William (1739-1823), who first revealed to Wilson the world of natural history. Just as Burns inspired Wilson to poetry, so Bartram not only inspired, but also instructed, Wilson in ornithology, and promoted his skill as a bird illustrator.

William Bartram

The gentle and friendly Bartram gave Wilson the run of his library, and brought to him almost a century of accumulated knowledge and disciplined observation of the American wilds. Through Bartram, Wilson got to know Charles Willson Peale, founder of the then internationally known Museum of Natural History in Philadelphia, which Wilson used as a studio and repository for his bird specimens. Bartram also introduced him to the American President, Thomas Jefferson, himself no mean ornithologist.

William Bartram's major work was *Travels through North and South Carolina, Georgia, East and West Florida etc.*, published in 1791, and in it he listed 215 American birds. The book brought him considerable fame, not only among naturalists but also among the romantic writers of Europe, notably the English poets, Blake, Wordsworth and Coleridge. Mention has already been made of three revolutions, but there was a fourth, the 'Romantic Revolution', and this influence shines clearly through Wilson's writing in his *American Ornithology*. When the first volume came out in 1808 it was not the work of an untrained amateur, but of a man who had equipped himself for the first scientific listing and description of American birds, and no-one can ever take from Wilson his hard-earned and well-deserved title, 'The Father of American Ornithology'.

Wilson's Meetings with Audubon

Now we come to the meetings, later to be so controversial, between Wilson and Audubon, during the four days Wilson spent at Louisville, Kentucky, in March 1810, and later and very briefly at Philadelphia. Only the meeting at Louisville is of any consequence.

Louisville and Wilson's Diary

The Louisville meeting is only known from the writings of George Ord and Audubon. In the life of Wilson which Ord wrote (1814) for the final volume of the *American Ornithology,* he included what he said was an extract from Wilson's diary. Unfortunately, this diary or journal has apparently never been seen by anyone since it was in Ord's possession. I, for one, have searched long and hard for it, but entirely without success. Although Ord exhibited the diary to the American Philosophical Society in 1840 (see later), it was not in Ord's library, willed to the College of Physicians and Surgeons in Philadelphia when he died in 1866, so its present whereabouts, if it still exists, must be regarded as unknown. The extract

from the diary, which makes no mention of Audubon, runs as follows:

> "March 23d. I bade adieu to Louisville, to which place I had four letters of recommendation, and was taught to expect much of everything here; but neither received one act of civility from those to whom I was recommended; one subscriber, nor one new bird; though I delivered my letters, ransacked the woods repeatedly, and visited all the characters likely to subscribe. Science or literature has not one friend in this place".

As already mentioned, the first parts of Audubon's *The Birds of America,* which were plates only with no text, began to appear in London in 1827, and in 1828 Ord edited and published another edition of Wilson's *American Ornithology*. This edition contained extended extracts from this mysterious diary of Wilson's. Apparently Wilson lodged at the Indian Queen Tavern, where Audubon and his family also lived, and the extended journal, as printed by Ord, stated that Wilson saw "Mr .....s drawings in crayons - very good. Saw two new birds he had, both *Motacillae* (warblers)". Again, according to the printed account, Wilson went out shooting on 20th March and wrote "No naturalist to keep me company". On the following day was noted, "Went out shooting with Mr. A. saw a number of Sandhill Cranes. Pigeons numerous".

Audubon's Doubtful Version of the Louisville Meeting

The matter should have rested there. What did follow was a hornets' nest disturbed by Audubon himself, when in 1831, twenty-one years after Wilson visited Louisville, Audubon began to publish his *Ornithological Biography,* the separately published text to accompany the plates of *The Birds of America*.

Audubon's version of the Louisville meeting was that one morning in March 1810, Alexander Wilson, of whom Audubon had never heard until that moment, walked into his counting-house. Wilson carried under his arm the first two volumes of his book, *American Ornithology,* for which he was seeking subscribers.

Audubon said he looked at the plates and was about to sign when his partner, Ferdinand Rozier, called from the back of the store in French "My dear Audubon, what induces you to subscribe to this work? Your drawings are certainly far better, and again you must know as much of the habits of American birds as this gentleman". At that, Audubon changed his mind, or as he put it, "I did not subscribe to his work, for, even at that time, my collection was greater than his".

Audubon then claimed that he showed Wilson a portfolio of his own bird paintings, and Wilson asked if he intended to publish. Audubon said that he answered in the negative, and later commented "and indeed such was not my intention; for, until long after, when I met the Prince of Musignano in Philadelphia, I had not the least idea of presenting the fruits of my labour to the world". Audubon also said that he obtained birds for Wilson which Wilson had never seen before, and added that he offered Wilson the results of his researches and his services as a correspondent, to which Wilson made no reply.

The last claimed remark is indeed extraordinary in view of Wilson's known enthusiasm to have reliable correspondents throughout America, and whose names are meticulously given in the letterpress of the *American Ornithology,* particularly when he had Audubon's confirmation that he had no intention of publishing. All throughout his formidable expedition through America, Wilson wrote long narrative letters to his friend and engraver, Alexander Lawson, describing in detail his experiences and the people he met, from the commencement of his journey at Philadelphia, to Pittsburgh and then by rowing boat 720 miles down the Ohio River, to Louisville, and continuing through wild territory to New Orleans. Never once, however, did he mention meeting the 25-year old Audubon.

Charles Lucien Bonaparte

Here I must interject a little bit about the 'Prince of Musignano', in other words Charles Lucien J.L. Bonaparte, whom Audubon met at Philadelphia in 1824. Today Bonaparte is chiefly remembered as the man who published a continuation of Wilson's *American Ornithology,* in four volumes (*American Ornithology; or the Natural History of the Birds inhabiting the United States, not given by Wilson, &c.* Philadelphia, 1825-1833). In Francis Hobart Herrick's definitive life of Audubon, *Audubon the Naturalist* (New York, 1917; 2nd edition, 1938), it is recorded that Bonaparte was very anxious to have Audubon illustrate his continuation of Wilson's book; but when he introduced Audubon to Alexander Lawson, Wilson's engraver, there was a clash. Lawson said that Audubon's drawings were anatomically incorrect, and refused to engrave them. Eventually, however, Lawson did agree to engrave one of Audubon's birds, the Boat-tailed Grackle or Great Crow Blackbird, which appeared as Plate 4 in Volume One (1825) of Bonaparte's continuation of Wilson's *American Ornithology*.

We are left with a fascinating conjecture; would Audubon's *Birds of America* ever have been published if Bonaparte could have induced Audubon and Lawson to work together on his

continuation of Wilson's unfinished work? From the moment of his rejection by Lawson, however, it is clear that Audubon was torn between respect for Wilson and a harboured resentment.

Further Diary Entries

There is a contradictory entry in this perplexing diary of Wilson's, a diary which in its original form appears to have contained spontaneous reference notes never intended for other eyes, although we have also to consider that there may have been some injudicious editing by Ord. This contradictory entry was one of those amplified in 1828, and it states that Wilson parted with his paroquet to "the gentlemen of the tavern" at Louisville before he left.

Now this is very much at odds with Wilson's own writings in the *American Ornithology,* where he refers to capturing his Carolina Parrot at Big Bone Creek on the Ohio River en route to Louisville; and he goes on to tell of experiences with the parrot, which was still with him between Nashville and Natchez, then at William Dunbar's plantation near Natchez, and when he arrived at New Orleans. Finally he tells, rather sadly, that when he was sailing home the bird flew overboard in the Gulf of Mexico and perished.

Doubts

My own view is that Audubon's account of the Louisville meeting, twenty-one years after the event, is sheer fantasy, deliberately invented by Audubon in an attempt to present himself in a more favourable light; other examples of similar behaviour by Audubon are well known. Or possibly, to be more charitable, at best it may have been a very cloudy recollection and ultimately self-deception, occasioned by Audubon's deep desire to imagine his own earlier involvement with the subject in the light of his subsequent success.

The extracts from Ord's rendering of Wilson's diary, however, may also be suspect, possibly understandably. That there was some plagiarism of Wilson by Audubon is undoubted, and it may be that George Ord, justifiably angry, over-reacted and attempted (quite unnecessarily) to bolster his charges of plagiarism by doctoring Wilson's diary, which in the circumstances he later had to destroy. Clearly it would have been far better to let the undoubted facts speak for themselves, and simply to draw attention to them in a suitable scientific journal, to the best of which Ord certainly had access.

It is doubtful if the paragraph about Wilson's visit to

Louisville, as first printed by Ord in 1814, caused Audubon any concern, but the expanded version in 1828 clearly did sting him, and from then on the brickbats flew between Wilson's supporters and Audubon and his faction.

Audubon's Unjustifiable Claim

Audubon's claim that in 1810 his collection of birds was greater than Wilson's is highly unlikely to be true, for two very good reasons. Firstly, by 1810 Wilson had covered very much more of America, from the Canadian border to the deep south, for the specific purpose of ornithological study; secondly, Audubon did not then have the technical support available to Wilson from the active help of important observers of the calibre of William Bartram, Meriwether Lewis, John Abbot, President Thomas Jefferson, and others. One should also consider the ages of the two men, respectively 25 and 44 years, undoubtedly a world of experience apart.

Wilson as Audubon's Inspiration

In 1966 the original Audubon water-colour paintings were published (*The Original Water-Color Paintings by John James Audubon for The Birds of America*. New York Historical Society, 1966), thus enabling detailed comparisons to be made with the Havell engravings of the drawings. These original water-colours confirmed that Ord's charges of plagiarism had a factual basis, but some of the arrows should have been aimed at Robert Havell Junior, the outstanding London engraver whose skill added an extra dimension to the finished plates, for Havell borrowed from Wilson in one or two notable instances.

How much better the good names of both Audubon and Wilson would have been served if only Audubon had acknowledged what the passage of 150 years would indicate to be Wilson's due - that at least Wilson made Audubon's task much easier. I go further, and I am by no means alone in this, in believing that the meeting in Louisville was the springboard which inspired Audubon to become a serious ornithologist and ultimately to publish his spectacular enterprise *The Birds of America*.

Wilson an Innocent Bystander

The fierce arguments about the respective merits of Alexander Wilson and John James Audubon are now in the past, but we should always remember that Wilson was an entirely innocent party in the Ord/Audubon controversy. Wilson himself neither wrote nor spoke one single derogatory word about Audubon. Indeed he would have had no reason to do so, for Wilson could never have had any cause to imagine for one moment

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M.D., Professor of Anatomy in the University of Pennsylvania," which was referred to a committee.

Mr. Ord directed the attention of the Society to the following passage in Audubon's "Birds of America." Article, *Small-headed Flycatcher.*

"When Alexander Wilson visited me at Louisville, he found, in my already large collection of drawings, a figure of the present species, which, being at that time unknown to him, he copied, and afterwards published in his great work, but without acknowledging the privilege that had thus been granted to him. I have more than once regretted this, not by any means so much on my own account, as for the sake of one to whom we are so deeply indebted for his elucidation of our ornithology."

"This attack upon the reputation of a member of this Society," said Mr. Ord, "one who, during the long period that he dwelt amongst us, was noted for his integrity, ought not to be suffered to pass without examination."

Mr. Ord submitted to the inspection of the Society, Wilson's Autograph Diary of his journey from Philadelphia to New Orleans, viâ Pittsburg and Louisville, commencing on the 30th of January, 1810. From this diary it appears, that he arrived at Louisville on the evening of Sunday, the 18th of March; and departed thence for Frankford and Lexington, on the morning of Friday the 23d. During his stay at Louisville, he was occupied three days in soliciting subscribers, and endeavouring to get materials for his work, and one day he was employed in writing to his friends at home. Four days, consequently, were passed in Louisville, one afternoon of which was devoted to shooting, in company with Mr. Audubon; and a portion of a morning was appropriated to examining that gentleman's collection of crayon drawings; in which Wilson states he saw the figures of two new birds, both *Motacillæ* or Warblers; but he does not state that he saw a figure of a *Muscicapa* or Flycatcher. He does not say a word respecting the loan of Mr. Audubon's drawings, nor does he give the least reason to suppose that he made a copy of any of the drawings; on the contrary, he positively asserts that he did not get one *new* bird at Louisville.

Mr. Ord proceeded to examine the style of both Audubon's and Wilson's drawings, and pointed out the peculiarities of each author. He declared, that the figure of Wilson's Small-headed Flycatcher differs in no respect from his ordinary style; that it bears the signet of paternity on its very front. But, as it might be objected that this mode of reasoning is inconclusive, from the circumstance of several of Mr. Audubon's birds bearing a resemblance to those of Wilson, Mr. Ord obviated this objection, by stating that Mr. Audubon had not scrupled to appropriate the labours of Wilson to his own use; inasmuch as the figure of the female March Blackbird, (Birds of America, plate 67,) and that of the male Mississippi Kite, (same work, plate 117,) had both been copied from the American Ornithology, without the least acknowledgment of the source whence they had been derived. Mr. Ord thought that the charge of plagiarism came with an ill grace from one who had been guilty of it himself, as in the instances above mentioned.

Wilson states, that he shot the bird figured and described in his 6th volume,

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page 62, in an orchard, on the 24th of April. Mr. Ord confirmed this statement, by declaring to the Society, that he himself was with Wilson on the day in question; that he saw and examined the specimen; and that Wilson assured him it was entirely new to him. Wilson was then residing at the Bartram Botanic Garden, near Philadelphia.

Mr. Ord farther read to the Society a letter addressed to him by the artist, Mr. Lawson, who engraved the plate in which the Small-headed Flycatcher is figured. This gentleman affirms, that all the plates, which he engraved for the American Ornithology, were from Wilson's own drawings; and that with respect to the plate in which the Small-headed Flycatcher appears, *specimens* of all the birds there represented accompanied the drawings; and he, after getting his outline, *worked from them*. Mr. Ord laid before the Society a proof of the etching of this plate, and remarked, that from the minuteness of the details, the *point* of the engraver had evidently a greater share in producing the desired result, than even the pencil of the ornithologist.

Mr. Lea, from the Publication Committee, reported, that the first part of the 7th volume of the Transactions of the Society was completed, and presented a copy thereof for the inspection of the members.

Mr. Vaughan stated, that agreeably to the instructions of the Society, he had purchased the Anamitic and Latin, and Latin and Anamitic Dictionaries, lately published by the Right Reverend Father Taberd, Bishop of Isauropolis, and Vicar General of Cochin China; in two volumes, 4to. Serampore, 1838. (See Proceedings of July 3.)

Dr. Hays made an oral communication relative to the operation recently devised for squinting, and to its effects in modifying the adjusting power of the eye for near and distant objects.

Dr. Hays stated, that certain phenomena which he had observed in one of the cases in which he had divided the internal rectus muscle, for the cure of squinting, seemed to favour the theory of the adjustment being made by an alteration in the form of the eye, under the conjoint action of the four recti muscles; a theory rejected by the best physiologists of the day.

The case, the details of which Dr. Hays related, was that of a gentleman thirty-six years of age, who had squinted with his left eye since the age of five years. Both the eyes were presbyopic; the left, however, was most so, and required for distinct vision a glass three Nos. higher than the other eye; the respective Nos. being 11 and 14. Vision with the left eye, even by the aid of a glass, was not

that he had a possible rival in the person of the virtually unknown Audubon, who, by his own admission, only commenced work on his *Birds of America* in 1820, seven years after Wilson's death, by which time Wilson's *American Ornithology* had become the accepted standard work on the subject. Audubon, however, was less fastidious, and made several unwarranted and unsupported attacks on Wilson.

The most notorious concerned a very rare bird indeed, the Small-headed Flycatcher, which has apparently only been identified and illustrated by two ornithologists; first by Wilson and then two decades later by Audubon. George Ord's detailed rebuttal of Audubon's claim appeared in the *Proceedings of the American Philosophical Society* for 1840. The American Philosophical Society is the oldest and most respected scientific society in the United States. Wilson was made a member in 1813 and Ord was an active member for many years. Audubon, too, eventually became a member. For those genuinely interested in the affair, the original account in the Society's *Proceedings* has been reproduced on pages 92 and 93, and in my view it can safely be allowed to speak for itself.

Wilson the Pioneer

We have to accept that Audubon was able to complete his masterpiece, whereas poor Wilson died with his great work incomplete. This, however, does not detract from the magnitude of Wilson's endeavours and achievements over ten years, from the conception of his idea "to make a collection of our finest birds" until his death.

In his drawings, Audubon the flamboyant Frenchman sought dramatic effect and succeeded wonderfully well, whereas Wilson the cannier Scotsman aimed for precise facts and accurate delineation. Wilson was the observant pioneer, whose drawings, in all the honesty of what is today called the primitive or naive style, were brought alive by the artistry of his commentary; while Audubon, without doubt the finer artist, built upon the work of Wilson with his own splendid drawings.

Audubon, and his engraver Havell, used Wilson's book as a standard guide, and there is really no reason why Audubon should have pretended otherwise. It would not have diminished Audubon to give due credit to the long dead Wilson for his groundwork, just as Wilson made acknowledgement to Bartram and others. Wilson cleared the ground and planted the seed, and later Audubon reaped the crops.

This later borrowing from Wilson's original work did not cease with Audubon; many subsequent authors did the same. As

Dr. Casey A. Wood pointed out in his *Introduction to the Literature of Vertebrate Zoology* (Oxford University Press, 1931): "There probably has never been an American treatise on zoology so thoroughly exploited and out of which so many composite works have been fashioned - so many veritable cold literary dishes - as Wilson's *Ornithology*".

A Final Assessment

My own views are clear-cut and well known, but I should like to negate any modicum of personal prejudice you may have suspected in this paper, by ending with two comments by distinguished American authors:

Firstly, from Dr. Elliott Coues' renowned four-volume pioneer bibliography (*Ornithological Bibliography*. Washington, 1878-1880). Coues said of Wilson's *American Ornithology*, "Science would lose little, but, on the contrary, would gain much, if every scrap of pre-Wilsonian writing about United States birds could be annihilated".

Secondly, from Dr. Elsa Guerdrum Allen's authoritative study *The History of American Ornithology before Audubon* (1968; reprinted from *Proceedings of the American Philosophical Society*, 1951). She wrote: "When Wilson and Audubon are compared as scientists and not as artists, Wilson's greater exactness, his patient method and his lucid and honest descriptions mark him unquestionably as the better ornithologist".

Mr. Clark Hunter, 20 Leeburn Avenue, Crossleewood, HOUSTON, Renfrewshire PA6 7DN.

THE FIRST RECORD OF THE LESSER RORQUAL IN DUNBARTONSHIRE

EVIDENCE FROM AN EARLY PHOTOGRAPH

By J.A. GIBSON
Clyde Area Recorder,
Mammal Society of the British Isles

Neither in my account of the marine mammals of the Clyde area (Gibson 1976), nor in my later paper on the mammals of Dunbartonshire (Gibson 1984), was I able to give any authentic Dunbartonshire record of the Lesser Rorqual *Balaenoptera acutorostrata*, a relatively uncommon whale in West of Scotland waters.

In June 1905, however, a report of an unidentified whale stranded at Dumbarton Rock had been published in the *Campbeltown Courier* (Anon. 1905a). The report was apparently abstracted (a common occurrence) from another West of Scotland newspaper, most probably the *Glasgow Herald,* although attempts to trace the original report were unsuccessful.

The whale was said to be some 17 feet long, but no other useful details were given, and following the failure to trace any original report, in my Clyde marine mammal paper (Gibson 1976) I suggested that, from the reported size, the specimen would most probably have been a Bottle-nosed Whale *Hyperoodon ampullatus*, always far and away the commonest cetacean to be stranded on Clyde shores.

There the matter rested until January 1986, when Mr. John Mitchell, of the South-West Scotland Region Nature Conservancy Council, quite by chance in Dumbarton Reference Library found some very battered copies of an old postcard of the 1905 Dunbartonshire stranded whale (not identified, but well displayed on a cart) and very kindly sent me a photocopy.

To merit the production of such a postcard, the stranded whale must clearly have been an event of considerable local interest, so the existence of a contemporary local newspaper report was also very likely. According to the evidence of the postcard, no attempt had apparently been made to identify the whale, but the date and length were given (21st June 1905, and length $17\frac{1}{2}$ feet). The weight was also said to be two tons, but whether this was simply a guess, or had been accurately measured at one of the public vehicular weighing stations, was not stated.

With the kind assistance of Mr. Graham Hopner, Dumbarton District Reference and Local Collections Librarian, a detailed search later uncovered a much better copy of the postcard in the Dumbarton Public Library archives, and on this postcard, which I have carefully examined, the photograph shows an obvious baleen whale (jaws propped open, showing the baleen plates) with a distinct white patch on the flipper, which, with the size, makes its identification as a Lesser Rorqual very clear.

A further search soon revealed the anticipated local report, a paragraph in the local weekly newspaper, the *Lennox Herald* of 24th June 1905 (Anon. 1905b), which is worth quoting in full, as follows:

> On Wednesday afternoon last, a whale was taken from the river Clyde, here, off Helenslee, and is now being exhibited within the burgh. It is said it was first seen in the vicinity on Tuesday evening, at anyrate, on Wednesday morning it was noticed in the river. The tide was receding at the time, and, it is thought, it was one or two steamers coming up about the same time which chased the monster up the river, and made her wallow over the Black Bank into the sandy shallows. Here she was stranded high and dry, and some of the townspeople who were on the lookout, soon had her staked down to the shore, ropes being passed round the tail, and lower jaw. When the tide rose again, however, the whale burst her bonds, and made up channel. Boats were soon in pursuit, and managed to seize the trailing ropes. With these the big fish was again stranded, and having been destroyed, was loaded on a lorry and taken into the town. It now lies at the rear of the Elephant Hotel, where it is being exhibited. It is claimed by Mr. John Wright, the Brothers Ponsonby, and another man named Gillies, and has attracted a great deal of attention. In length it is 17ft., and in girth 12ft. Its lower jaw measures 3ft. 8ins. by some 2ft. across the broadest part. From tip to tip the tail is 4ft., and the approximate weight is 3 tons. It is described as a young female bottlenose, or herring whale. So far as is known, there is no record of a whale having been captured so far up the river before. Some time since a somewhat similar specimen came ashore at Greenock, while, in 1855, Dr. McLachlan tells us that a skeleton, 40ft. long, was unearthed from the shore at Erskine, and is now in the Hunterian Museum. As to the final disposal of the Dumbarton whale, nothing is yet definite, but the suggestion is freely made that its skeleton ought to be preserved, and placed in some such keeping as the Denny Institute Museum.

A few points require to be made. The distressing account of the chase, with all attempts being made to capture and kill, not to rescue, the whale, no doubt simply reflected the views of the time, when a whale was still apparently regarded as something of a prize, with some of the older men of the town probably having been whalers in their youth. Mr. Hopner tells me that Helenslee "is now Keil School, on the west bank of the Leven just above the Clyde. The account also refers to the whale coming beyond the Black Bank and becoming stranded with the ebbing tide. There is apparently, according to a member of staff, a ridge of sand off Keil School which she recalls from her childhood days as being called the Whale's Back" (Graham Hopner, *in litt.*).

The *Campbeltown Courier* report could not have been copied from the *Lennox Herald,* since the two newspapers were published on the same Saturday morning, 24th June 1905. A further search has still not revealed any report in the *Glasgow Herald,* so possibly each newspaper obtained the information independently. This is, in fact, quite likely to be the case, since the two accounts do differ in several respects, with the *Lennox Herald* account being much more detailed, and also more likely to be correct in the straightforward facts, since it was the established local newspaper of the district.

The original estimated weight of three tons had become two tons by the time the postcard was published, and the suggested identification as Bottle-nosed ('Iceland' in the *Campbeltown Courier*) was obviously just a guess, presumably based on the knowledge that specimens of the Bottle-nosed Whale had previously been stranded in the area. Even a cursory glance should have shown that the specimen was an obvious baleen (i.e. whalebone) whale, but three-quarters of a century ago whales were still somewhat mysterious creatures, and no-one with even an elementary knowledge of marine mammals appears to have seen the whale at the time.

After a lapse of over three-quarters of a century, therefore, the first authentic occurrence of a Lesser Rorqual in Dunbartonshire has been confirmed from the evidence of an early photograph. At the time, there was only one previous authentic record of a Lesser Rorqual for the entire Clyde sea area (Gibson 1976). This is a very good illustration of the value of carefully preserving all early photographic material, and the information obtained from this investigation has also been transmitted to the Scottish Society for the History of Photography.

Unfortunately, even the best available copy of the postcard is not of a quality suitable for reproduction in a

scientific journal, but a copy of the original postcard has kindly been presented by Mr. Hopner and has been deposited in the Scottish Natural History Library.

I am very grateful to Mr. Mitchell and Mr. Hopner for the discovery and assistance which made possible the authentication of this early record.

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Dr. J.A. Gibson, Foremount House, KILBARCHAN, Renfrewshire PA10 2EZ.

SHORT NOTES

LONG-EARED BAT AT AUCHENBRECK, COWAL

On 16th June 1987 I found a dead specimen of the Long-eared Bat *Plecotus auritus* at the roadside on the outskirts of Auchenbreck, Cowal, Argyll. The specimen was very fresh, and the identification was immediately clear. As previously noted (*Western Naturalist,* 10: 25. 1981) I have been visiting the Auchenbreck area for many years, and have several sightings of bats which were almost certainly Long-eared, but this is my first positive record. The Pipistrelle *Pipistrellus pipistrellus* is common in the area.

I understand that the Long-eared Bat is fairly widely distributed throughout the Clyde faunal area (*Glasgow Naturalist,* 19: 259-301. 1976), but I consider that this occurrence is worth recording since it represents a further addition to the 10-kilometre square NS08 as given in the *Atlas of Cowal Vertebrates* (1980). J.P. Henderson

LONG-EARED BAT ON THE GREAT CUMBRAE

On 10th August 1987 I found a freshly dead specimen of the Long-eared Bat *Plecotus auritus* on the driveway of a house in West Bay Road, Millport, Island of Great Cumbrae. In the paper on the mammals of the Cumbrae islands by J.A. Gibson and R.O. Shillaker (*Western Naturalist,* 3: 23-30. 1974) it is stated that the last known record of a Long-eared Bat for the Great Cumbrae was in May 1945, so this additional record is worth noting.

The specimen was initially placed in the freezer at the University Marine Biological Station, Millport, and was later transferred to the Biological Records Centre at Monks Wood.

Roger Powell

(The Long-eared Bat is certainly widely distributed throughout the Clyde faunal area, and is undoubtedly much more common than the meagre records from some areas would indicate, so it is always worth while recording any specimens examined in the hand, even if simply to establish the identity as *P. auritus*. To the best of my knowledge, there is as yet no evidence that the Grey Long-eared Bat *Plecotus austriacus* occurs anywhere in the Clyde faunal area. J.A. Gibson, *Clyde Area Recorder, Mammal Society of the British Isles*).

GRASS SNAKE AT KILBARCHAN, RENFREWSHIRE

On 4th October 1986 a specimen of the Grass Snake *Natrix natrix* was found on a roadside verge just to the north of the village of Kilbarchan, Renfrewshire. The specimen measured 23½ inches in length and was alive when first found, but unfortunately died during the night. It had two small contusions near the middle of its body, as though it had been slightly injured by the edge of a car wheel.

Grass Snakes were formerly commonly kept as pets, although are not nearly so common nowadays and have not apparently been stocked by local pet shops for many years, and extensive local enquiries have revealed no evidence of the source of the specimen. In the past there have been occasional records of Grass Snakes from Renfrewshire, and other parts of the Clyde area, and there is even a well-authenticated record of breeding (*Western Naturalist,* 5: 113-114. 1976). In the absence of further evidence, all records are presumed to be escapes, but it is always useful to place any occurrences on record.

J.A. Gibson

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